

DEPARTMENT OF THE INTERIOR, CANADA

HON. THOMAS G. MURPHY, Minister

H. H. ROWATT, Deputy Minister

FOREST SERVICE—BULLETIN No. 80

E. H. FINLAYSON, B.Sc.F., Director of Forestry

T. A. McELHANNEY, B.A.Sc., Superintendent Forest Products Laboratories of Canada

BRITISH COLUMBIA SOFTWOODS
THEIR
DECAYS AND NATURAL
DEFECTS

BY
H. W. EADES, B.Sc.F.



OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1932

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T. A. McElhanney, B.A.Sc., Superintendent

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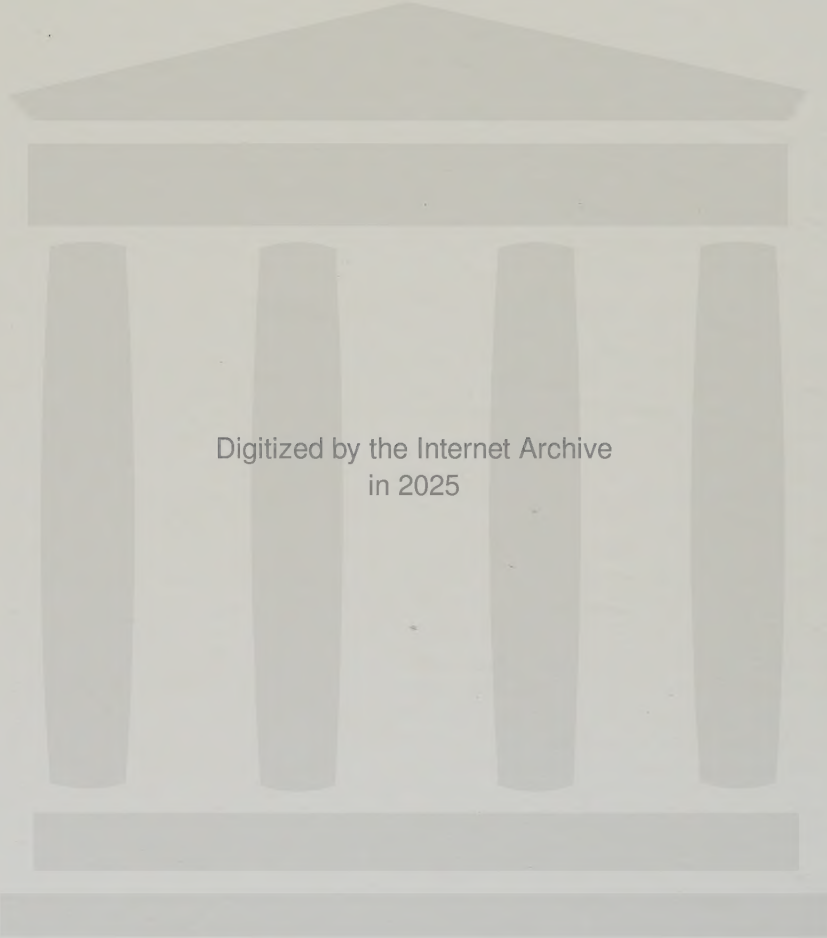
PREFACE

This publication is a result of insistent inquiries from the lumber industry of British Columbia for comprehensive and graphic information concerning the appearance and significance of the rots, stains, and other natural defects which may be encountered in the softwoods of the province. It attempts to give information not only upon *defects*, but also upon the commoner *blemishes* and discolorations, a knowledge of the cause and significance of which will enable the grader to apply his grades correctly to lumber containing them. Supplemental information upon the structure and physiology of wood tissues, which should naturally precede discussion of wood defects, is included. Only naturally produced defects and blemishes are dealt with in this publication. Manufacturing defects are not nearly as wide-spread; millmen have little difficulty in locating them and in understanding their significance, and grading rules are generally sufficiently specific in regard to them.

Only very limited explanation is given in grading rules regarding the appearance of the various common forms and stages of decay in softwoods. "Soft spots" and "white specks," for example, are rather ambiguous terms, which in themselves are not enlightening to the inexperienced. Particular attention is given herein, therefore, to the stains and discolorations produced by wood-inhabiting fungi (the cause of sap stain and decay), the demand for information in this direction being greatest. A number of photographic plates are included showing the common types of rots and stains. In some cases the plates are coloured.

For several years educational classes have been conducted at several of the principal lumbering centres of the province, under the auspices of the British Columbia Lumber and Shingle Manufacturers, Limited. The Vancouver Forest Products Laboratory, Forest Service, Department of the Interior, Canada, has been able to assist these classes in some of their technical problems. Although this publication was intended, primarily, to be a description of the natural defects found in wood, it was felt that some of the information compiled by the Forest Products Laboratories for these classes (much of it relating directly to lumber defects) might very well be included in it. This information has been compiled, together with other relevant matter, in logical sequence, which should make it readable and readily understood, even by those whose preliminary education has not included courses in botany, chemistry, physics, forestry, and other sciences. Debatable points, abnormalities in lumber, common fallacies about wood which should rightly be corrected, have been given particular attention. Such points of interest have been, and still are, brought to the attention of the Laboratory either through the classes or through more private inquiry.

The text has been written, as far as possible, in non-technical language, and liberal use has been made of diagrams and photographs. It is hoped that this booklet will serve as a work of reference or as a text-book for graders and those who wish to learn something about the defects and blemishes and the pathology of wood. It does not pretend to show one how to grade lumber, for that can be done only by the aid of actual experience in handling it.



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**British Columbia Softwoods: their Decays and
Natural Defects**

**A Discussion of their Appearance, Cause, and Significance
in Lumber Grading**

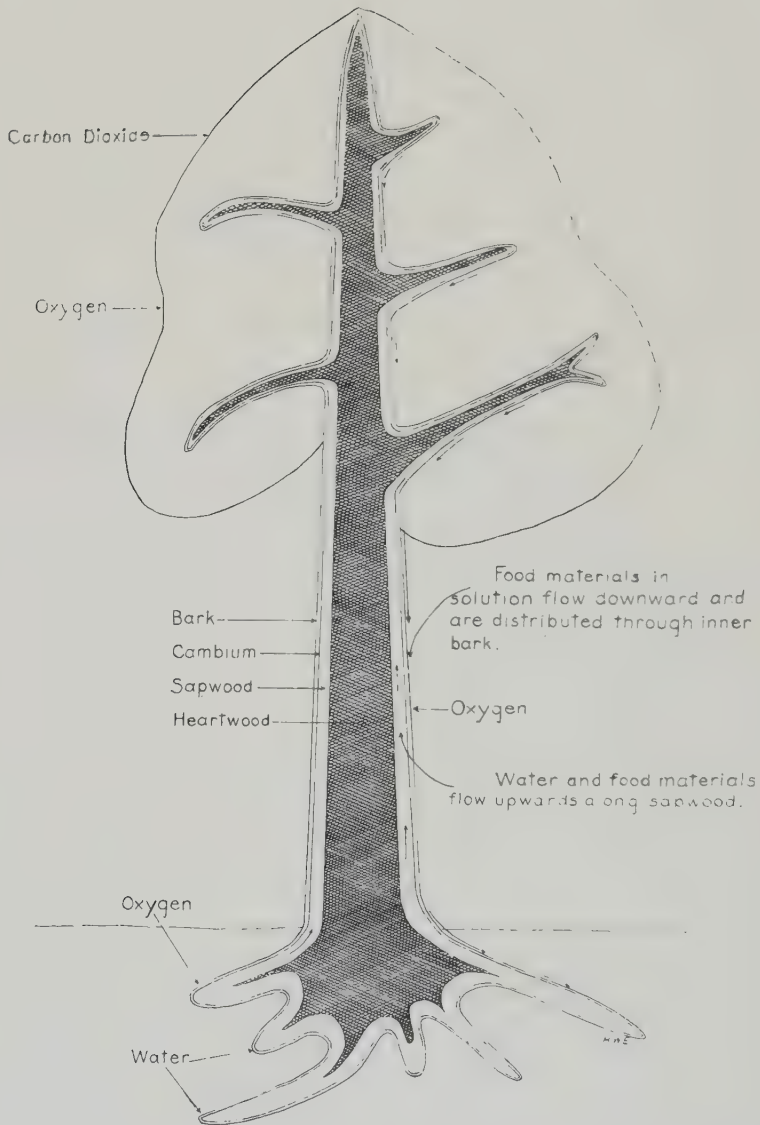


FIG. 1—DIAGRAM SHOWING MAIN PARTS OF A TREE AND HOW FOOD IS MANUFACTURED AND DISTRIBUTED

CHAPTER I

GENERAL ANATOMY AND PHYSIOLOGY OF A TREE

Parts of a Tree

A tree may be considered as being made up of three main parts, namely, *root*, *trunk*, and *crown*. The roots extend into the ground to a depth and width of spread that depend very much on the kind of tree and the kind of soil in which the tree is growing; they take up water and certain mineral substances that are essential to tree life from the soil, and they give anchorage and support to the tree. The trunk, bole, or stem affords mechanical support to the branches and crown, and is the channel through which nourishment is carried to the latter. The crown, with its branches, foliage (leaves or needles), and buds, comprises the third portion of the tree; in the green portions of the foliage the food materials taken up from the soil are remanufactured and made available for consumption by the tree.

The form, or shape and character, of the tree-trunk is of greater importance than the volume of wood contained therein. If the tree is straight, approaches a true cylindrical shape, and is clear of knots, branches, and other defects, its value for lumber purposes will be greater than if its form deviates from a true cylindrical shape and contains many branches, knots, and other defects. The freer a trunk is from branches, and the straighter the bole, the more clear lumber can be cut from it. As a rule, trees grown in pure or dense stands are straighter and freer from branches than trees grown in mixed or open stands. Age, environment, and structural characters peculiar to the species all have an effect in determining the quality of the lumber which can be obtained from an individual tree.

If a cross-section of trunk, root, or branch be cut, it will be seen that the woody material consists of three dissimilar portions. In the centre of the cross-section is a narrow, soft cylinder of *pith*. At the outer limit of the section is a layer of *bark*, while between the bark and the pith is the *wood proper*. The wood may itself be differentiated into two portions—*sapwood* and *heartwood*. The sapwood is lighter in colour than the heartwood, has a higher moisture content when the wood is green, and may be as much as several inches in width, depending upon the age of the tree and its species. One may differentiate the gross structure of the cross-section, therefore, from pith to periphery, into pith, heartwood, sapwood, and bark.

Structure of Wood

Cells.—Every tree is an aggregation of *cells*. The wood-cells of softwood trees are hollow and much elongated, and resemble pipes. Apart from providing mechanical support, the main function of these pipes is the conduction of food materials up and down the tree. They are very small in diameter, so that a cross-section under a powerful hand-lens or a microscope shows several thousands of them to the square inch. In cross-section they are seen to be four-sided to polygonal in outline. A longitudinal section shows them to have constricted or tapering terminations. These

vertically arranged *tracheids*, as they are called, comprise the bulk of the woody structure of softwoods. Interspersed among the tracheids may be found certain tubular passages known as *resin ducts*. These are lined with small specialized cells known as *parenchyma*, which are able to manufacture resin. There are also a number of larger parenchyma cells to be found among the tracheids. The parenchyma cells are shorter than tracheids, and have their terminations blunt instead of constricted; their chief function is the storage of food materials. In softwoods, parenchyma tissue is generally associated with resin formation.



FIG. 2.

DIAGRAM OF CELLS OF SITKA SPRUCE
WOOD, SHOWING STRUCTURE OF

- (1) Medullary-ray cells.
- (2) Longitudinal water-conducting elements (tracheids).
- (3) Bordered pits.
- (4) Simple pits.

(After Jeffrey.)

Not all the cells of a tree are arranged vertically. Some of them are arranged horizontally and radially, and comprise what are known as *medullary rays*.

The weight, strength, and hardness of different species of wood are due to the relative thicknesses of the cell-walls, and to the arrangement of the cells with respect to each other. In some species, such as Western red cedar and the true firs, the cell-walls are thin, and the wood is softer and weaker than Douglas fir. In Douglas fir the cell-walls are not as thick as those of oak, therefore oak is harder. The fibres in oak are not as straight as in Douglas fir, so oak is tougher and does not split as easily but the greater straightness of the grain of fir tends to make it stronger and stiffer than oak when used as a beam.

The wood-substance of the cells is composed of an intricate chemical complex, which, however, is homogeneous in the tree and does not vary greatly in all the softwood group. Indeed, the chemical composition of hardwoods and softwoods varies very little, so that in chemical analyses little difference can be detected. Species and individual trees do differ, however, in their chemical components when their extractives are considered, in regard to which there may be wide variations, due to the presence of resins, tannins, various mineral compounds in the cell contents, etc.

Medullary Rays

If a piece of coniferous wood—say, Douglas fir or Western hemlock—be split down a radial line (that is to say, a line extending from the centre of the tree to the bark) and examined, a series of fine parallel lines will be seen on the split section, crossing it at right angles to the grain. These fine lines are medullary rays or pith rays. Their function is to store up food supplies for the tree, and to assist in their circulation, acting as conduction channels from the inner bark towards the centre of the tree. They are also said to play a part in the process by which sapwood is eventually made more durable and converted into heartwood. The brownish colour of the rays is due to the presence of resin.

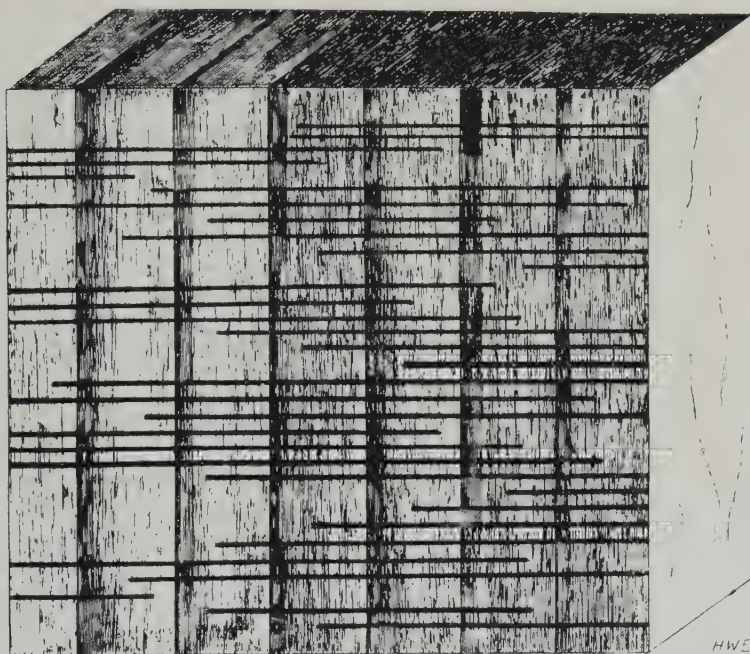


FIG. 3—DRAWING SHOWING MEDULLARY RAYS (greatly enlarged)

The wood section must be cut as nearly radially as possible in order to show the rays plainly.

Rays are composed of radial bands of more or less cylindrical-shaped, thin-walled cells, and are usually, in conifers, only one cell thick. They may be as much as twenty cells in depth (by depth is meant the distance to which they extend upward and downward in the trunk). They may contain resin ducts, in which case they are thicker than they would normally be, and may be two or three cells in thickness. Most ray cells are composed of parenchyma tissue, characterized by blunt endings, the presence of resin, and simple pits in their cell walls. Sometimes tracheidal tissue is found in the rays.

A few of the rays originate at the pith. As the tree grows in size, further new rays are produced at the cambium layer. Once formed, the growth of the ray is continuous and extends through to the bark. Rays are perhaps more noticeable in Douglas fir than in any other British

Columbia softwood, but even in Douglas fir the section examined must be cut exactly in a radial direction to show them up plainly. In spite of their lack of prominence, they form a considerable proportion of the wood substance of softwoods. It has been estimated¹ that medullary rays form, on an average, 7.8 per cent of the wood-substance of North American conifers. Medullary rays are much more prominent in hardwoods than in softwoods, and to their presence is due the fine "figure" of many hardwoods, especially those which have wide rays. "Quartered" oak is probably the most familiar example of this.

The diagram of the small piece of wood, greatly magnified (fig. 2), gives an idea of the structure of the cells and rays of wood.

Pits

When the cell tissue is first formed it consists of a thin primary wall only. As its growth progresses the cell becomes thickened internally, a secondary wall being added. In places the secondary wall is not entire, but has gaps in it of more or less circular form. The gaps are known as *pits*; they are of two main types—*simple* and *bordered*.

Simple pits generally take the form of circular canals or tunnels between cells, with the thin primary wall membrane left interposed in the centre of each canal or passage. The length of the canal is determined by

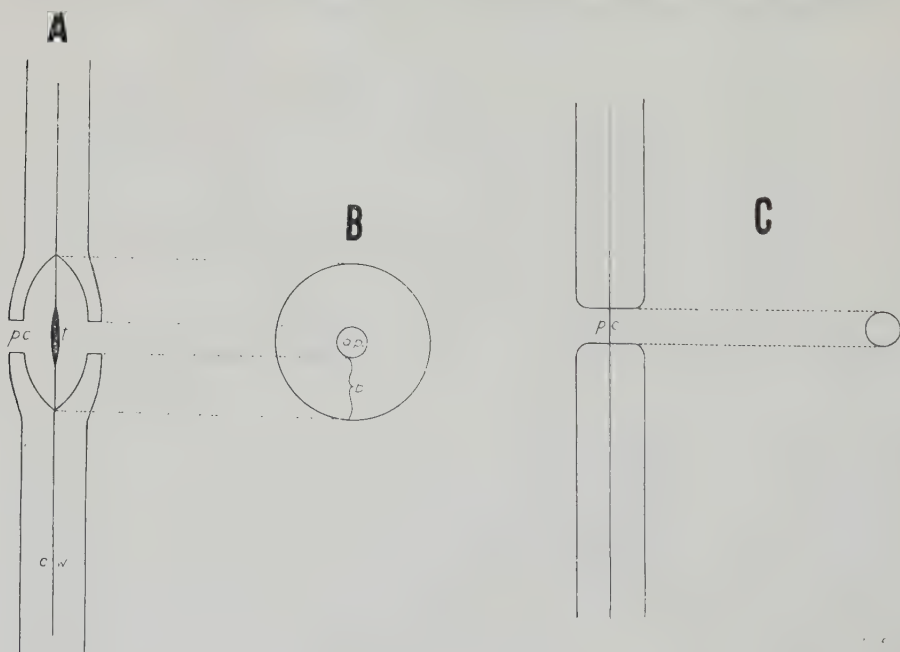


FIG. 4—DIAGRAMMATIC REPRESENTATION OF PITS (greatly enlarged)

- A. Section of bordered pit, showing cell walls (*c.w.*), pit canal (*p.c.*), torus (*t*). The torus is a thickened portion of the primary cell-wall.
- B. Another sectional view of the same bordered pit, showing aperture (*a.p.*) and border (*b*).
- C. Ordinary simple pit with pit canal (*p.c.*).

¹Myer, J. E. Ray volumes of the commercial woods of the U.S. Jour. For. XX: 4: 337-351. April, 1922.

the thickness of the secondary walls. In a bordered pit the canal widens suddenly towards the primary membrane, that is, the aperture of the pit is narrowest at its exit into the cell cavity and widest at the primary membrane. In a surface view under the microscope a bordered pit appears as a small, bright spot within a circle. The spot is the aperture of the pit, and the zone outside of it, terminated by the outer circle, the bordering portion of the cell-wall. Figure 4 shows a diagram of the structure of both kinds of pits.

Tracheidal tissue is always characterized by bordered pits, while simple pits are characteristic of parenchyma tissue. As tracheids form the bulk of the wood substance of softwoods, it will be obvious that bordered pits are much more numerous than simple pits in these woods.

In softwoods the prime function of bordered pits is to facilitate the passage and diffusion of sap in its rise from roots to leaves, while that of simple pits is to permit the passage and storage of elaborated food material. The primary membrane found in each pit is permeable by liquids.

The arrangement and occurrence of pits in various softwoods afford a valuable means of identifying these woods under the microscope.

Resin Ducts

Another prominent feature in the structure of wood is the *resin duct*. This is described on page 25.

Life Processes of a Tree

Being a living organism, a tree requires nourishment in order to live. It derives its food materials from two sources, namely, the soil and the air.

If the tips of the rootlets or root filaments be examined closely it will be noticed that they are covered with minute, fine hairs; these *root-hairs* perform the important function of extracting water and certain mineral constituents from the soil. These food supplies, in the form of a very thin solution, are passed by what is generally known as "osmotic pressure" through the sapwood of the roots, trunk, and branches to the leaves. This circulation is often referred to as the flow of sap. The force behind the circulation is imperfectly understood.

The leaves form a chemical laboratory, as it were, in which are carried on those processes which give life and growth to the tree. They take in from the atmosphere *carbon dioxide* gas, and this gas dissolves in the water contained by the leaves. In the leaves is a green pigment called *chlorophyll*, which has the remarkable property of using the energy of light to manufacture the elements contained in the watery solution and the carbon dioxide into complex carbon compounds, which form the greater part of the tree's food. This natural process of manufacture is known as *photosynthesis*. The surplus oxygen (a component of both carbon dioxide and water) passes off into the atmosphere, as does the surplus water. The quantity of water passed from the leaves of a tree into the atmosphere (in the *transpiration* process, as it is called) in a single growing season is enormous, and it can readily be understood that the atmosphere in and about a forest must be very humid while transpiration is going on, especially in warm weather, when the removal of moisture from the leaves by evaporation is greatest.

A third process carried on by the leaves is called *respiration*. During this process oxygen is taken from the atmosphere and carbon dioxide, the product of respiration, exhaled, in a similar way to the respiration or

breathing of animals. By this means energy through oxidation is provided to all the living cells of the tree. The interchange of gases which accompanies this important physiological process may take place not only through the leaves, but through other parts of the tree.

The manufactured food supplies, in the form of a sugary sap, are conducted from the leaves to the growing parts of the tree just underneath the bark, by way of the inner bark, or bast tissue, and the *cambium layer*.

The tree is able to grow through the assimilation of the food supplies manufactured in its leaves. In the initial stages of the tree's growth nourishment is circulated through the pith, which consists of a mass of loose cellular (parenchyma) tissue, extends in softwood trees in a continuous line from top to bottom of the trunk, and reaches out into the branches and smallest twigs. As soon as the sapwood and the cambium layer are developed, these usurp the functions of the pith, and the latter gradually becomes exhausted and dies. As the tree grows older, although some of the food supply goes to help the growth of leaves, buds, fruit, and new twigs, the bulk of the elaborated food material is drawn to the thin cambium layer which lies between the wood and the bark. Through the cambium, annual growth of wood is added to the tree's diameter. This layer is renewed each year and it actually grows into two parts during the growing season, the inner part adding new wood and the outer part adding fresh bark to that already formed.

Growth in girth or diameter is attributable entirely to the cambium layer. Growth in length takes place through the elongation of the terminal tissues at the ends of stems, branches, and roots.

Causes of Disease in a Tree

If the normal growing functions just described are interfered with, an abnormal condition ensues, and the tree may be said to be diseased. This bulletin is chiefly concerned with the effects of disease in the timber product, but at this point it is appropriate to dwell for a moment on the various causes of disease which occur in standing timber.

Leaf diseases, by partially or wholly killing the foliage, destroy the organs in which the tree's food is manufactured. The cambium does not receive the requisite nourishment, with the result that the tree's growth is halted. The delicate root-hairs, through which the transpiration stream enters the tree from the soil, suffer lack of nourishment and are not renewed, and, consequently, as soon as the supplies of food stored in leaves, medullary rays, sapwood, and inner bark are exhausted, no more water is supplied to the remaining foliage for the manufacture of food.

Diseases of the sapwood cut off the upward flow of sap normally supplied from the roots through the sapwood to the leaves, and so the leaves wilt or die of drought. The majority of the diseases of both heartwood and sapwood are caused directly by wood-inhabiting fungi, producing rot or decay, which may continue to operate in the wood after the tree has been felled and even cut into lumber, as long as physical conditions are suitable. Heartwood rots may hardly be called functional diseases, because the heartwood is dead material, as contrasted with the sapwood, which is living. If the rot is serious, it may affect the mechanical support of the tree and render it liable to windfall. The value of such trees for lumber, of course, is greatly lessened. Heartwood rots may spread to other portions of the tree and affect the sapwood or the root system. However, trees have been known to live for many years with hardly any heartwood remaining.

Diseases of the bark of trunk or branches intercept the flow of manufactured food which normally travels down the inner bark from the leaves. The result is a stoppage of growth of the cambium layer and roots.

Diseases of the root system have an effect on the water supply of the tree, and, if serious, may soon kill it.

These various types of disease may be caused directly or indirectly by old age, drought, frost, sunscald, drowning, fire, lightning, snowfall, cloudburst, wind, smelter fumes or smoke, or by mechanical injury due to the hand of man, to insects, rodents, and other animals, or to the action of wood-inhabiting fungi. A few minor diseases are due to bacterial action or the action of parasites such as mistletoe. Functional diseases may in many cases be considered to have little effect upon the quality of the lumber produced by a tree, but by stoppage of growth they obviously have an important effect upon the quantity of lumber produced by it. The secondary attacks of insects or wood-destroying fungi which ensue when the vitality of a tree has been thus reduced, or when injury has destroyed its natural armour against these organisms, are the causes of most of the actual disintegration of merchantable timber which takes place in the woods.

The youth or the maturity of a tree is not always a reliable criterion of the absence or presence of disease. Certain diseases are confined, however, to definite ages. Some fungi, for instance, attack only young seedlings, or young branches or twigs, while others are confined to mature or overmature trees. Generally it may be said that the older a tree is after reaching maturity, the more liable is it to fungous and insect attack.

Growth-rings

If a cross-section of a softwood log be examined, the wood is seen to be composed of a series of rings with a common centre. Each of these rings represents one year in the life of the tree. All British Columbia softwoods have these "*annual rings*." The light band of soft wood in the ring is the spring-wood, or early growth, while the darker-coloured band of harder wood is the summer-wood, or late growth. Most of the tree's growth takes place in the spring, so that the band of spring-wood is nearly always wider than the band of summer-wood. The summer-wood is harder because its cells are smaller and have much thicker walls than those of the spring-wood. This is due to the fact that when the leaves sprout afresh in the spring there is a demand for large supplies of sap, so that the pipes or cells then formed have thin walls and large openings. Later on, in summer, there is not as much need for conduction of the watery sap, and the cells then formed have smaller openings. The summer cells also have thicker walls because their apparent function is to give support to the tree rather than to conduct liquids. In the autumn, growth stops and it begins again the following spring in the form of pipes with larger openings. As this row of thin-walled cells is next to the row of thick-walled cells formed the summer previous, a distinct line of demarcation is formed, which is visible on a cross-section.

If a piece of wood contains a high percentage of summer-wood, then it is said to have a high "*density*," or weight per unit of volume. If the quantity of summer-wood present is small, then it is of low density. In mechanical tests of western species it has been found that there is a close relation between density and strength, and that the strength of wood increases with its density.

If the rings are wide, then the growth of the tree has been rapid; if narrow, then it has grown slowly. With the softwoods, or conifers, wood of slow growth is generally stronger and more desirable than wood of fast growth. Extremely slow-grown wood and wood from very old trees, however, are often weak. Rate of growth is not nearly as good a criterion of strength as proportion of summer-wood or density, but there is more or less relation between strength and normality of growth. Wood of abnormally fast or abnormally slow growth does not ordinarily have the same strength, or uniformity in strength, as wood of normal growth.

The terms "*virgin growth*" and "*old growth*" are often used interchangeably in referring to lumber with narrow annual rings, while rapidly grown wood with wide rings is often referred to as "*second growth*." The greater portion of the stands of merchantable timber in British Columbia, especially in the coastal region, are dense and sometimes overmature, and are now being cut over for the first time. Timber grown under these conditions is frequently characterized by narrow rings, hence the origin of the terms "*old growth*" and "*virgin growth*." The idea conveyed by the term "*second growth*" is that the stand has grown quickly, after the removal of the original stand by fire, cutting, wind, or other means.

The variation in thickness of annual rings within a species is due entirely to environmental factors, such as habitat, condition of the soil, drainage, density and type of stand, and the age or vitality of a given tree. The presence of narrow annual rings in a tree is no absolute criterion, therefore, that it came from a virgin stand or from a mature or overmature forest. Similarly, the presence of wide rings is no criterion that it came from a second-growth stand. The width of the rings forms an indication of the conditions under which an individual tree grew, but it forms no criterion of the condition of growth of the rest of the stand. A stand growing uniformly under what are known as "*second-growth*" conditions eventually slows up in its growth as the forest reaches maturity, so that the later annual rings may be no wider than the rings in a much older stand growing under "*old-growth*" conditions. On the other hand, when a slow-growing, suppressed forest tree is relieved from competition by removal of the neighbouring trees, it may grow rapidly for a long period. In this way it will be seen that it is easy for a single specimen to have the characteristics of both "*virgin growth*" and "*second growth*." The terms are really without fixed significance, and instead of depending on the width of annual rings or "*second*" or "*old*" growth to secure good material, it is a more reliable plan to depend upon density as a guide to quality, as long as the rings are neither very narrow nor very wide.

Occasionally when the growth of a tree has been checked in midsummer, owing to drought or defoliation, and then continued for the remainder of the season, an extra ring may be laid on. These false rings are fainter, more or less irregular, and generally easy to distinguish from normal growth-rings.

Heartwood and Sapwood

The inner portion of a softwood log, or heartwood, is usually darker in colour than the sapwood, or outer portion; this is due to the gradual infiltration into the cell-walls of chemical substances such as gums, resins, and tannins, from which the recently formed sapwood is comparatively free. The amount of sapwood present may vary (1) within a species, (2) between

individuals of that species, (3) in different portions of the same tree, and (4) sometimes even between different radii of a particular cross-section. It may be as much as several inches in thickness. The cells of the sapwood are comparatively young and fresh, and in a condition to permit the circulation of liquids, and it is in this portion of the wood that the rise of sap from roots to leaves takes place. The heartwood cells, on the other hand, become modified in the course of age so that they can no longer conduct sap, and their main function is that of mechanical support. Many trees live for years with considerable portions of the heartwood rotted away, but if the circulation of the sap is interrupted, as in "*girdling*" or "*ring-barking*," the tree will soon die from lack of nourishment.

On account of the usual difference in colour between sapwood and heartwood a distinct line of demarcation between the two is visible, although in a few species, like the true firs (balsams), the spruces, and Western hemlock, the difference in colour is not readily noticeable. Sometimes streaks of whitish sapwood will be found imbedded in the darker heartwood. This occurrence is especially noticeable in a species like Western red cedar, where the contrast in colour between the reddish-brown heartwood and the straw-coloured sapwood is great. It is purely an accident of growth and should not be confused with "mineral streaks," "hybrid species," "fungous growth," and the like. Such wood is generally referred to as "internal sapwood." An interesting explanation of internal sapwood is given in Stone's book²: "It is supposed, with great probability, to be caused by a frost severe enough to kill the sapwood and prevent it completing its metamorphosis into heartwood, without killing the growing layer or cambium. . . . The cambium can, therefore, continue to produce sapwood, which in due time becomes heartwood. The result is that we have an external sapwood zone, followed by a heartwood zone, then sapwood again and then heartwood. The very excellent brochure upon this subject, by Mer³ (1897), should be read by those interested in this curious phenomenon."

Conceivably other diseases of sapwood could produce the same effect. Boards cut from a "cat-face" or wound area, or from the swelling butts of cedar, may occasionally show a belt or streak of internal sapwood.

Usually heartwood of British Columbia softwoods is commercially more valuable than sapwood, partly on account of its attractive figure and colour, but more especially because of its greater durability under exposure. In some lumber grades, sapwood is considered a defect. For certain purposes sapwood is not considered inferior, however, as in material for manufacture of wood-pulp and in timber which is to be impregnated with preservatives. The best lumber is obtained from the outer heartwood, the inner heartwood containing a higher percentage of knots.

There is a widespread opinion that, normally, the heartwood of a softwood tree is stronger than the sapwood, but there is no evidence in support of such an opinion. The darker colour of the heartwood is due to the infiltration of certain substances into the wood, which, while they make it more resistant to decay, have no modifying effect upon the thickness of the cell-walls or the arrangement of the cellular structure. The basic structure of both sapwood and heartwood of an individual tree is usually identical.

²Stone, Herbert. A text-book of wood. London, 1921.

³Mer, E. La Lunure du Chêne. Extr. Bull. de la Soc. des Sci. de Nancy, 1897.

Moisture in Lumber

Newly cut logs from living trees contain a considerable percentage of moisture, no matter at what time of the year the tree is cut, for the quantity of moisture in a softwood tree varies little the whole year through.⁴ Green or freshly cut lumber may contain from 30 to 100 per cent, or even 200 per cent of moisture (based on the oven-dry weight of the wood). In softwoods, sapwood contains a much higher percentage of moisture than heartwood, but considerable variations in moisture content may occur in different parts of both heartwood and sapwood. The softwoods contrast with the hardwoods in this respect, the latter showing a fairly uniform distribution of moisture throughout sapwood and heartwood. The moisture in the sapwood is really the "sap" of the tree which has been manufactured in the leaves and sent downward for distribution, together with water which has risen from the roots, containing various mineral elements beneficial to the tree, and used in food manufacture. Western hemlock and amabilis fir have high moisture contents; spruce contains less, while Western red cedar and Douglas fir contain still less moisture.

Before green lumber can be put into use, most of this moisture must be removed, because

1. Green lumber shrinks and alters its shape in drying;
2. Freight charges, based on weight, are lessened;
3. Lumber with a high moisture content is subject to stain and decay;
4. It must have a low moisture content in order to "dress" or "surface" well;
5. Very wet lumber does not receive or retain paints well;
6. The strength of the wood varies with its condition of dryness.

In wood, moisture occurs hygroscopically in the cell-walls, and as free water in the cell cavities. In the process of drying, the free water inside the cells passes off first. The moisture condition obtaining when the cell-walls remain saturated though no free water is left within the cells is known as the "*fibre-saturation point*." It has been found that any reduction in moisture below the fibre-saturation point causes an increase in the strength of the wood, together with a certain reduction in volume. The increase in strength is closely related to the decrease in moisture content. In Douglas fir the fibre-saturation point occurs at a moisture content of approximately 23 per cent. This point for most wood species lies between 23 and 30 per cent of the oven-dry weight of the wood, varying with the species.

Reduction in moisture content is accomplished commercially by air-seasoning or by kiln-drying. In the coastal region air-seasoning in the open takes from two months to over a year, depending upon atmospheric conditions and the size of the stock. One-inch Douglas fir stock may dry thoroughly in two months in summer, whereas thick timbers may take a year or more. Efficient kiln-drying, on the other hand, may take only a few days.

Bark

The functions of the bark are

- (1) To distribute food materials manufactured in the leaves (through the inner bark or bast tissues);
- (2) To protect the delicate cambium layer, and the wood underneath it.

⁴Craib, W. G. Regional spread of moisture in the wood of trees. Notes from the Royal Bot. Garden, Edinburgh. Vol. 11, No. 51, 1918; Vol. 12, No. 59, 1920; Vol. 14, No. 64, 1923.

The new layer of bark laid on each year causes an annual ring or growth-ring to be formed in the bark, but the rings are much flattened by pressure and are hard to detect. As the tree increases in size, the layers of bark become more and more cracked and furrowed, owing to the internal pressure. The cedars (red and yellow) are an exception to the rest of the commercial softwoods in this respect. Their barks are stringy and fibrous and not nearly so thick as the bark of trees like Douglas fir, Western yellow pine, or Western larch.

The table given hereunder is compiled from data given by Sudworth, and shows how the barks of western conifers vary in thickness. Unless specifically mentioned, the figures given are for mature trees at breast-height; younger trees naturally have thinner bark.

Table of Bark-thickness

Douglas fir.....	Commonly 5 to 10 inches thick: may be as much as 24 inches thick near base of tree.
Western red cedar.....	Thin: $\frac{5}{8}$ -inch to $\frac{7}{8}$ -inch on old trunks.
Yellow cedar.....	On old trees about $\frac{5}{8}$ -inch.
Spruce (Engelmann and Sitka).....	Thin: rarely more than half an inch thick.
Western hemlock.....	$1\frac{1}{4}$ to $1\frac{1}{2}$ inches thick on old trunks.
Western white pine.....	Up to $1\frac{1}{4}$ inches thick.
Western yellow pine.....	2 to 4 inches thick.
Western larch.....	3 to 6 inches thick near base.
Lodgepole pine.....	Pacific Coast species, up to 1 inch thick: in Interior, thinner than this.
True firs.....	1 inch thick or less, rarely $1\frac{1}{4}$ inches on old trunks.

Barks contain resin ducts, crystals, tannin sacs, and other elements and structures. The bark of many trees is of commercial value. Western hemlock bark has a high tannin content, which can be extracted by leaching with hot water, the concentrated extract being used for tanning hides to make leather.

Bark-pockets

Sometimes pockets of bark of varying size may be found imbedded in the interior of any Western softwood. Small bark-pockets are common in Western hemlock, and pockets of larger size are frequently found in

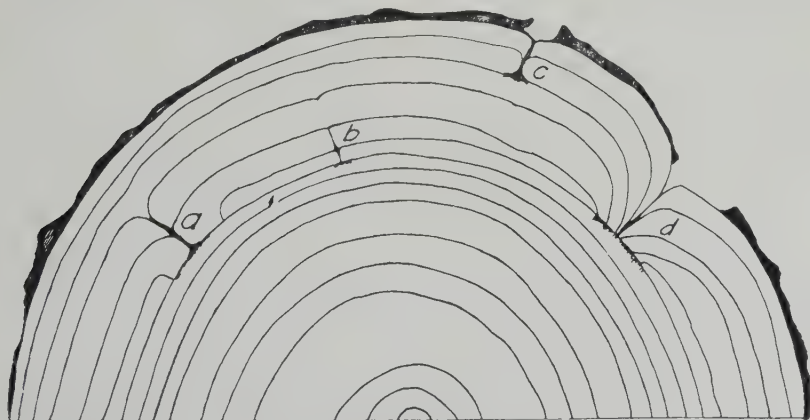


FIG. 5—SECTION OF A DOUGLAS FIR TRUNK SHOWING HOW BARK-POCKETS MAY BE FORMED. Each ring in the diagram represents 10 years' growth. At *a* and *b* the wounds have been entirely occluded. At *c* and *d* they are not completely occluded.

(After Hartig)

Douglas fir. They are the result of mechanical injury, insect or bird injury, sun scorch, or sudden acceleration of the rate of growth, which has caused rupture of the bark and consequent temporary exposure of the cambium layer at these places. Growth is halted locally until the adjacent cambium has produced wood which can grow over the exposed surface and occlude it, leaving a portion of bark imbedded within the wood.

In Western hemlock the galleries of certain insects, when healed over by a gummy or resinous excretion from the tree, often assume the aspect of small bark-pockets. These shallow cavities caused by insects heal over rapidly, as a rule, and new wood soon grows over them. Sometimes the pockets may not heal over quickly, so that bark is formed in them and small "bark-pockets" result. These bark-pockets in hemlock, however, will nearly always contain a certain quantity of the resinous excretion. The defect is often known as "black check" or "black streak," and is quite common in Western hemlock. Similar pockets may be caused by bird pecks. Slight local distortion of the grain sometimes accompanies such injuries.

In Douglas fir and in Western larch there are sometimes found large bark-pockets, which are due to the inclusion of a quantity of bark about a knot, around which the wood has grown. These are referred to as "*bark burls*." Bark burls are not considered to be a defect in any of the common grades of lumber.

Wane

Sometimes certain boards which have been improperly trimmed will have pieces of bark adhering to them. Such boards are considered defective and the defect is described as "*wane*." Not only may wane be ascribed to bark, but lack of wood on the edges of any piece of lumber from any cause is called "*wane*."

Knots

A knot in a piece of lumber indicates the occurrence of a branch. As the tree grows in diameter, protruding branches are increasingly enveloped by the new growth of the wood. The imbedded portion is roughly cone-shaped, with the apex at the pith. Branches originate, as a rule, at the pith of the trunk, and when living increase in diameter and length by the annual addition of new wood at the same time and in the same way as the rest of the tree. The tissues of a branch form an uninterrupted union with those of the trunk, on the lower side of the branch. On the upper side the wood elements bend aside, and are not continuous into the limb, hence the connection here is imperfect. If a bolt of wood containing such a knot be split from the top, the line of cleavage does not enter the knot, but passes to one side of it. If split from below the branch the cleft is likely to enter the knot.

Some branches do not originate at the pith but sprout from the side of the trunk; such branches are rare, however, in forest-grown material. Where the saw or the planer knife passes through the pith a defect is produced on the surface of the piece.

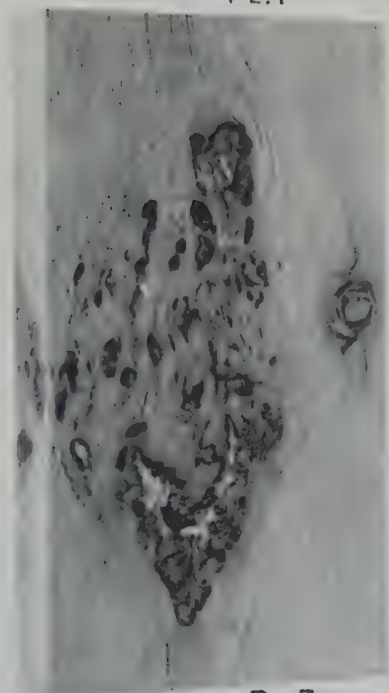
A young tree, or a tree which stands in the open, and receives a maximum number of light rays, usually has a larger number of limbs and branches. During the growth of the tree many of the lower branches die and drop off, their food-manufacturing functions having ceased owing to light being cut off from them. This result is especially noticeable in pure, thick stands of timber, and is known as "natural pruning." The best



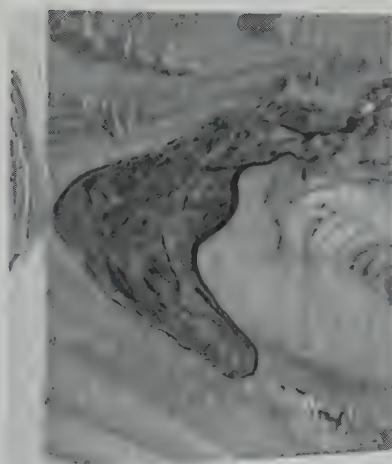
PL.1



PL.2



PL.3



PL.4

PLATE 1—Bark-pockets in Western Hemlock
 PLATE 2—Pith as it appears in a board of White Pine
 PLATE 3—Bark-pocket in Western Yellow Pine
 PLATE 4—Bark burl in Douglas Fir

stands of timber in British Columbia grow naturally in a dense condition, so that the lower branches drop off at an early stage in the life of the tree. For this reason the lower portion of the trunk usually has a high percentage of "clear" timber, i.e., lumber free from knots and other defects and blemishes. Knots are the commonest cause of low-grade lumber. If it were not for knots the percentage of upper grades would be tremendously increased.

When the dead branch falls, its stump remains and is gradually covered by successive growth-rings, until it is finally completely covered. Such branch stubs, especially if long, may not be connected intimately with the fibres of the tree, with the result that the wood surrounds the knot but leaves it "loose." Loose knots may drop out after the tree has been cut into lumber. Sometimes knots and the disturbance of the grain in the neighbourhood of a knot increase the value of the wood for special purposes, e.g., for furniture, owing to the fact that an unusually figured grain is created, but this applies more to hardwoods than to softwoods.

Knots are generally classified in grading rules as *pin*, *small*, *medium*, and *large*, as to size; *round* and *spike*, as to form; and *sound*, *unsound*, *decayed*, *tight*, *loose*, *intergrown*, and *encased*, as to quality.

Pin	Small	Medium	Large
Not over $\frac{1}{2}$ inch in diameter.	Over $\frac{1}{2}$ inch but not over $\frac{3}{4}$ inch in diameter.	Over $\frac{3}{4}$ inch but not over $1\frac{1}{2}$ inches in diameter.	Over $1\frac{1}{2}$ inches in diameter.

The diameter limits of knots should be construed to mean the average or mean diameters.

A *round knot* is oval or circular in form.

A *spike knot* is one sawn in lengthwise direction.

A *sound knot* is red or black, solid across the face and as hard as the adjacent wood.

An *unsound knot* is not as hard as the surrounding wood, and may contain incipient decay.

A *decayed knot* contains typical or advanced decay.

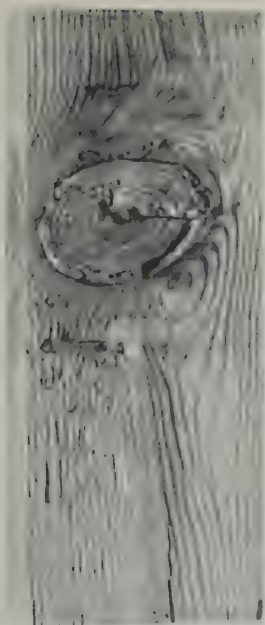
A *tight knot* is one that is so fixed by growth or position that it will retain its place in the piece.

A *loose knot* is one not held firmly in place by growth or position.

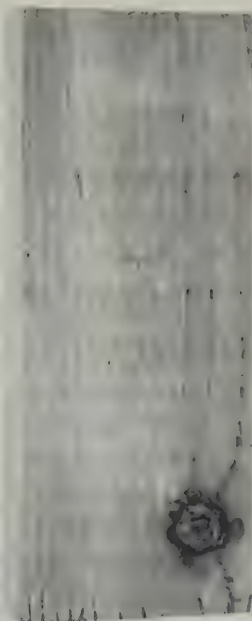
An *intergrown knot* is one whose wood elements are intergrown with those of the surrounding wood.

An *encased knot* is one which has not intergrown with the wood of the piece. The encasement may be either pitch or bark and may be partial or complete. If partly intergrown or so fixed by growth or position that it will retain its place in the piece, and otherwise solid across the face, it is considered a sound and tight knot. If completely intergrown on one face, it is considered a water-tight knot.

Knots, as a rule, decrease the strength of wood, especially large knots. Sound knots do not affect the strength of wood as much as loose knots.



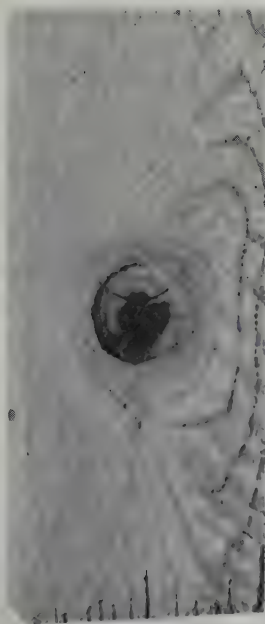
PL.5



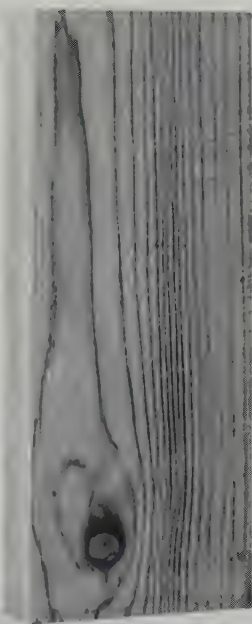
PL.6



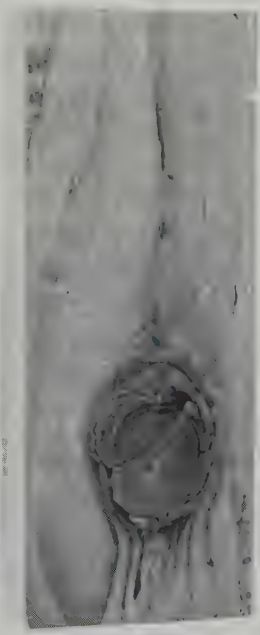
PL.7



PL.8



PL.9



PL.10

PLATE 5—A loose knot
PLATE 6—A decayed pin knot
PLATE 7—A loose spike knot

PLATE 8—A sound knot
PLATE 9—A pin knot
PLATE 10—An encased knot

Figure 6 gives a vertical view of an average Douglas fir log and shows how the imbedded branches or knots would appear if one could see through the log.

It will be seen that the tree has grown beyond the ends of most of the branches. Some of the branches are rotten for some distance back (indicated by shaded portions in the sketch). Towards the heart of the tree the majority of the knots become red and sound.

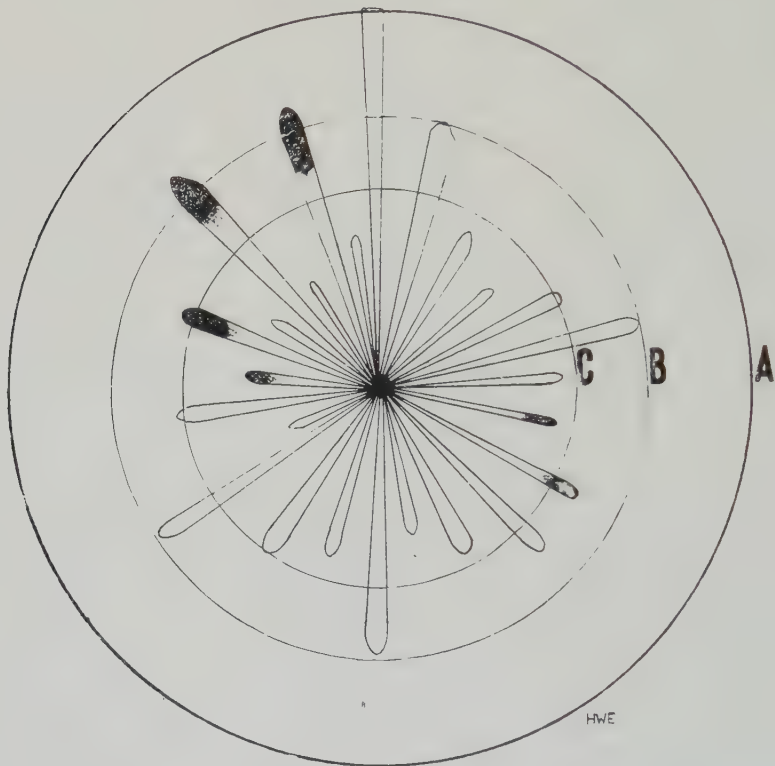


FIG. 6—DIAGRAM SHOWING "X-RAY" VIEW OF A DOUGLAS FIR LOG, AND THE POSITION OF THE KNOTS

Wood has grown beyond the ends of most of the branches. Some of the branches are rotten for some distance back (indicated by shaded portions in the sketch). Towards the heart the majority of the knots become red or sound.

Clear lumber (lumber free from knots and defects) extends from the bark to where the knots begin to show up—from A to B in the sketch. This lumber is made into finish, flooring, stepping, drop siding, and other high-grade products and usually comprises about 20 to 30 per cent of the average log. A few knots penetrate into the "clear" portion of the log, but these can be trimmed off with little waste. It is impracticable to cut clear lumber from the section B to C, because of the accumulation of short lengths and waste. Shop lumber, however, in short lengths can be cut from the inside of the log. The bulk of the inside of the log goes into the "common" grades, or the export grade of "merchantable."

Grain

Grain is a somewhat loosely used term referring to the arrangement of the wood elements and the appearance they may produce in the cut lumber. The kinds of grain commonly mentioned are fine, coarse, even, uneven, rough, smooth, straight, cross, spiral, diagonal, twisted, interlocked, wavy, curly, bird's-eye, edge or vertical, slash or flat, and angle grain.

With the softwoods, wood is called *fine-grained* when the annual rings are narrow and *coarse-grained* when they are wide. The terms *old-growth* and *second-growth*, respectively, have the same meanings. The terms *even* and *uneven* grain apply to the regularity or irregularity of the growth-rings; *rough* and *smooth* to the manner in which the wood works under tools.

As applied to the structure or texture of the wood elements of a tree, wood is said to be *straight-grained* when the direction of the wood fibres is parallel to the axis of the stem in which they occur, or as nearly parallel as the natural taper will allow. Sometimes the fibres may be twisted in a spiral direction about the tree, in which case the wood is said to have *spiral grain*. Where the grain is not constant in a general direction or is twisted or distorted, the wood is said to have *interlocked grain*. The terms *spiral grain* and *cross grain* are often applied to such wood, but they are not nearly as applicable as the term "interlocked grain" for describing a twisted condition of the fibres. Such wood is liable to be below strength, and tends to warp and twist in seasoning.

As applied to a board, *straight grain* occurs when the tangential and radial planes of the wood structure are parallel to the edge of the piece, and *cross-grain* where they are not. Cross-grained pieces may be cut through carelessness from a straight, normal log, and they are liable to be cut from a swelling butt or from a crooked log. Timber loses considerably in strength when the planes of its fibres are not parallel to the planes of its length. For this reason split timber is usually stronger than sawn, the splitting having taken place along the line of the fibres. Billets for handles and similar purposes, certain aeroplane parts, and matches are generally split.

Spiral grain may be detected by the expedient of dropping ink upon the flat-grained face of a board. The direction in which the ink follows the fibres will determine the presence of spiral grain. It may also be detected by observing the direction of the medullary rays, the resin ducts, and cracks or checks, or by the direction of the grain of splinters on the surface of the piece. Considerable further study is required before the cause of spiral grain can be determined. Heredity, the effect of wind currents, and variation in the supply of moisture and sunlight have been cited as possible causes. One authority estimates that during the war 70 per cent of overseas shipments of Sitka spruce for aeroplane purposes were rejected on account of spiral grain. This defect is found in all softwoods to some extent.

The wood elements may occasionally take a wavy form in a longitudinal and radial direction, producing a "wavy grain." When the waves are small in size, but numerous, the result in the wood is the "curly" structure common in maple.

The surfaces of the annual ring just under the bark and the successive layers underneath are, as a rule, smooth. Sometimes little channels and pits of varying shape, due to wounds of various kinds, occur on the outside

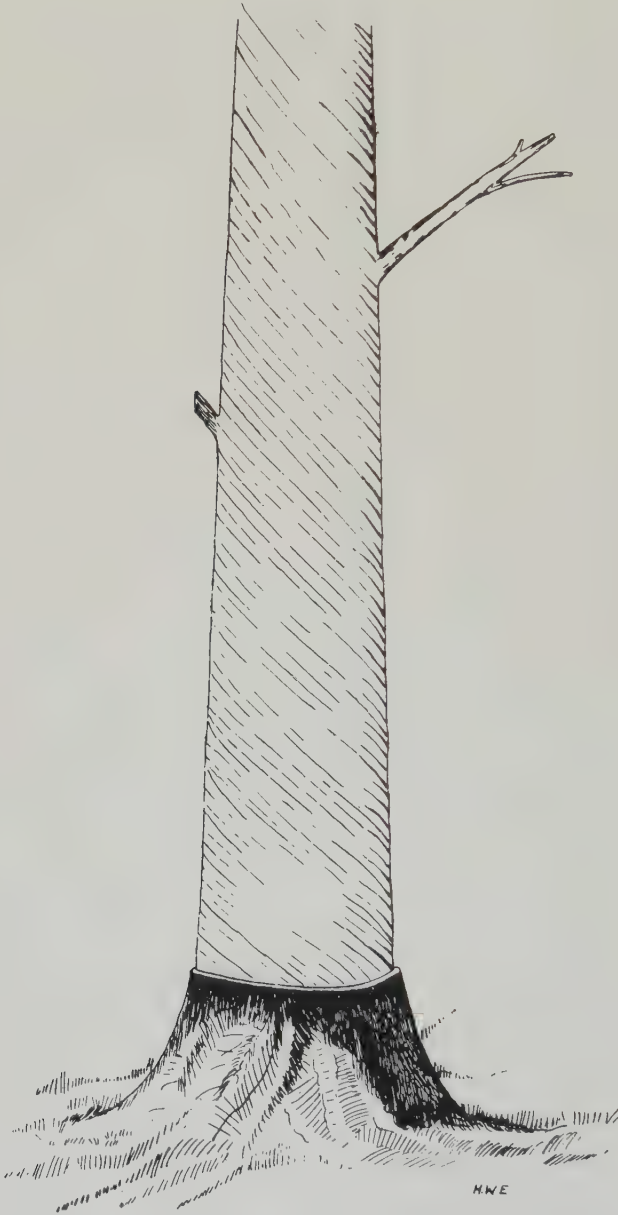


FIG. 7—SKETCH ILLUSTRATING SPIRAL GRAIN
Season-checks after removal of the bark indicate the direction of the grain.

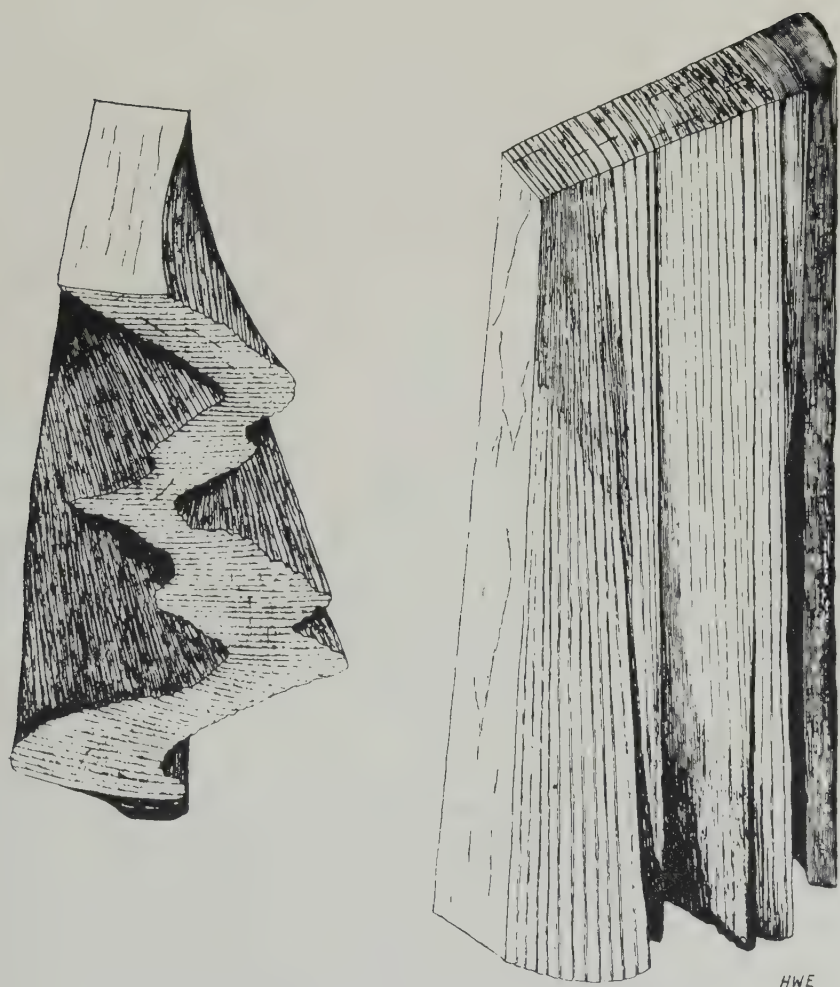
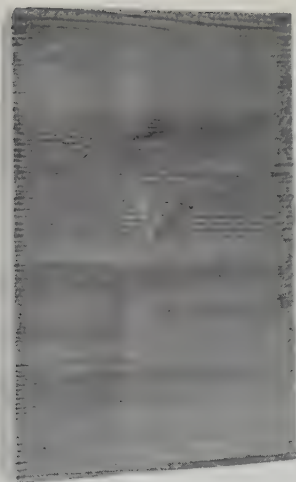


FIG. 8—EXAMPLE OF ALTERNATING SPIRAL GRAIN IN WOOD

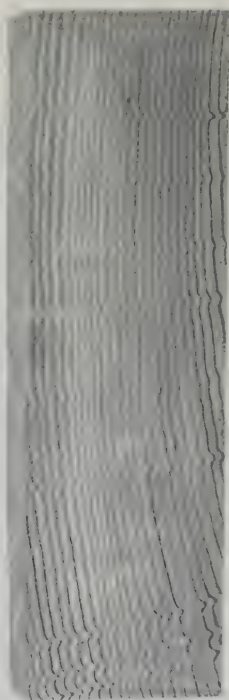
(After Roth)

of the outermost ring. Usually two or three years' growth is sufficient to fill up and even out these cavities, making the layers of wood quite smooth again, but occasionally the depressions are persistent and recur from ring to ring, throughout the life of the tree. In maple the prominences and depressions appear on tangentially cut or slash-grained boards as little circular marks, and produce what is known as "bird's-eye" maple. This kind of maple is greatly valued for panelling, furniture, and other special uses.

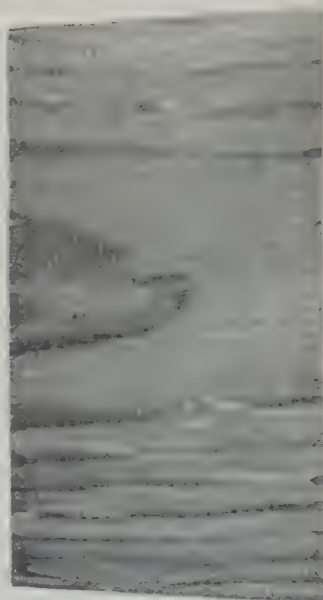
The causes of the wounds which may cause these small, persistent depressions in the grain of western softwoods include adventive buds, mistletoes, and the action of cambial fungi. The depressions may be extremely numerous when they originate from any of these three causes, may persist throughout the life of the tree, and be found in every annual ring and all portions of the trunk. Wound depressions which originate as



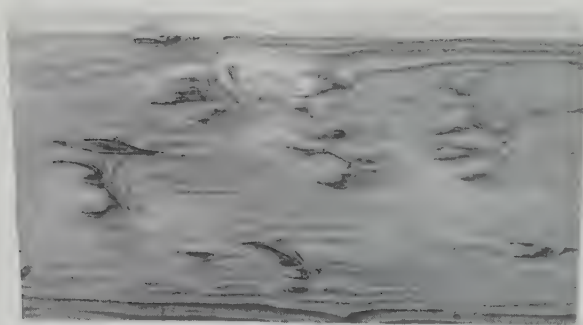
PL.12



PL.13



PL.14



PL.15

PLATE 12—"Bird's-eye" in Western Red Cedar

PLATE 13—"Bear-scratch" in Sitka Spruce—end section

PLATE 14 "Bear-scratch" in Sitka Spruce tangential section. (Reduced to half size)

PLATE 15—Distortion of grain found in Western Hemlock

a result of the injuries of woodpeckers, animals, fire, abrasion by falling limbs, or other cause, and the hand of man will usually be completely occluded and leave no dips in the grain after the lapse of a few years, except in cases where the wound is extensive.

Adventive buds may be annually produced upon an individual tree in great profusion, stimulation of their growth resulting from the attacks of fungi and mistletoes. Most of the buds do not develop beyond the bud

stage, and in the next year's growth they are covered up, leaving, however, a number of depressions in the annual ring and a consequent disturbance in the symmetry of the ring, which recurs during following years.

Another kind of adventive bud is not entirely dormant, but is capable of growing in thickness and putting on wood every year: it does not grow in length owing to some functional derangement. In the course of years such growths may be several feet in diameter, and the grain in them very irregular and very hard. On the trunk of the tree they appear as gnarled, warty lumps of varying size, and are generally referred to as "*burls*." Large burls (especially those from hardwoods) when cut through produce a diversified figure which is greatly prized for table tops, veneers, and other special uses. In softwood boards, burls sometimes destroy the continuity of the grain and are reckoned as a defect, especially when they contain bark ("*bark burls*"), or are loose. Burls or burrs may also be caused by wounding, by the occlusion of branch stubs, or by the growth of mistletoe. As a result of the wound the local growth functions are disturbed and the result is the callus or excrescence known as a burl, which is capable of growth from year to year. Mistletoes may cause distortions of the grain by sending their "*sinkers*" into the wood, or may produce the bird's-eye appearance indirectly by causing proliferation of adventive buds. Incidentally, *pitch streaks* are common in mistletoe-infected wood, the pitch being produced by the tree in an effort to combat the encroaching parasite. (See also plate 22, page 120.)

Cambial fungi seem to be responsible for a great deal of local grain distortion.⁵ The action of these fungi is not uniform throughout the cambium, but occurs only in spots here and there. The fungus halts the growth activity of the cambium at these places, but as the cambium about them continues to function in a normal way, the places where the fungus has been at work are made apparent by the formation of sporadic pits or depressions. These little depressions persist from year to year and a single series may last for twenty or more years until it is finally obliterated. Meanwhile other depressions may occur at other places in the cambium and continue in the same way, so that it is possible for the markings to be in evidence throughout all the wood of a tree.

In Douglas fir and Western red cedar such a cambial affection causes a bird's-eye appearance [see plates 11 (page 119) and 12], in Western hemlock a blemish peculiar to that species (see plate 15), and in Sitka spruce the appearance known as "bear-scratch" (see plates 13 and 14). Although woodpeckers, mistletoes, and adventive buds may cause the bird's-eye appearance in fir and cedar, and the peculiarly figured blemish of spruce and hemlock, the occurrence of a parasitic fungus appears mainly to account for these local grain distortions, as well as the bird's-eye of maple, cottonwood, amabilis fir, lodgepole pine, and Western yellow pine, particularly in cases where their occurrence is very persistent and prolific.

The normal grain of wood, whether due to the medullary rays or the annual rings, can be modified and displayed in different ways by various modes of cutting or sawing the log. If the grain of a wood is displayed so as to exhibit a pleasing design, then it is said to possess a good "*figure*."

For grading purposes grain is classified as "*edge-*," "*angle-*," or "*flat-grain*." Edge-grain consists of lumber cut at an angle of not more than forty-five degrees from the vertical. The term has the same meaning as the expression "*quarter-cut*" as applied to oak. As conifers have not the wide medullary rays of oak, the edge-grain boards cut from the former

⁵Hale, J. D. Forest Products Laboratories of Canada, Ottawa.

cannot, of course, approach the fine figure of the latter. By cutting the log as closely as possible to the radial direction the maximum number of bands of alternate summer- and spring-wood is obtained. Edge-grain boards, as a rule, have better wearing qualities than flat-grain; they are much easier to season, warp and check less, and command a higher price. Edge-grain flooring, siding, shingles, etc., are more desirable than flat-grain material. Edge-grain lumber sometimes goes by the name of "rift-sawn" or "vertical-grain" material.

Flat-grain, sometimes called "slash-grain," consists of lumber cut at an angle of more than sixty-five degrees from vertical. Angle-grain consists of lumber cut at an angle of not less than forty-five degrees, but not more than sixty-five degrees from vertical. The term "angle-grain" is not used as frequently as the terms "edge-" and "flat-grain."

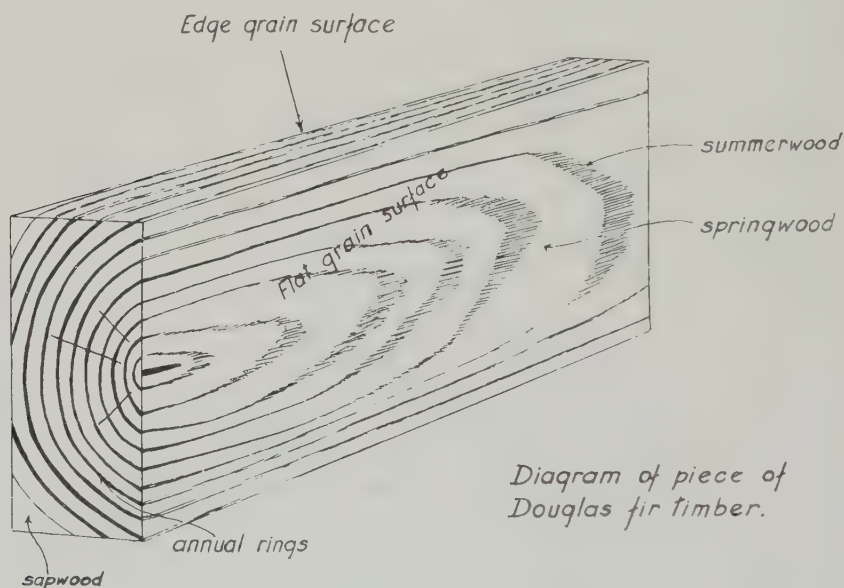
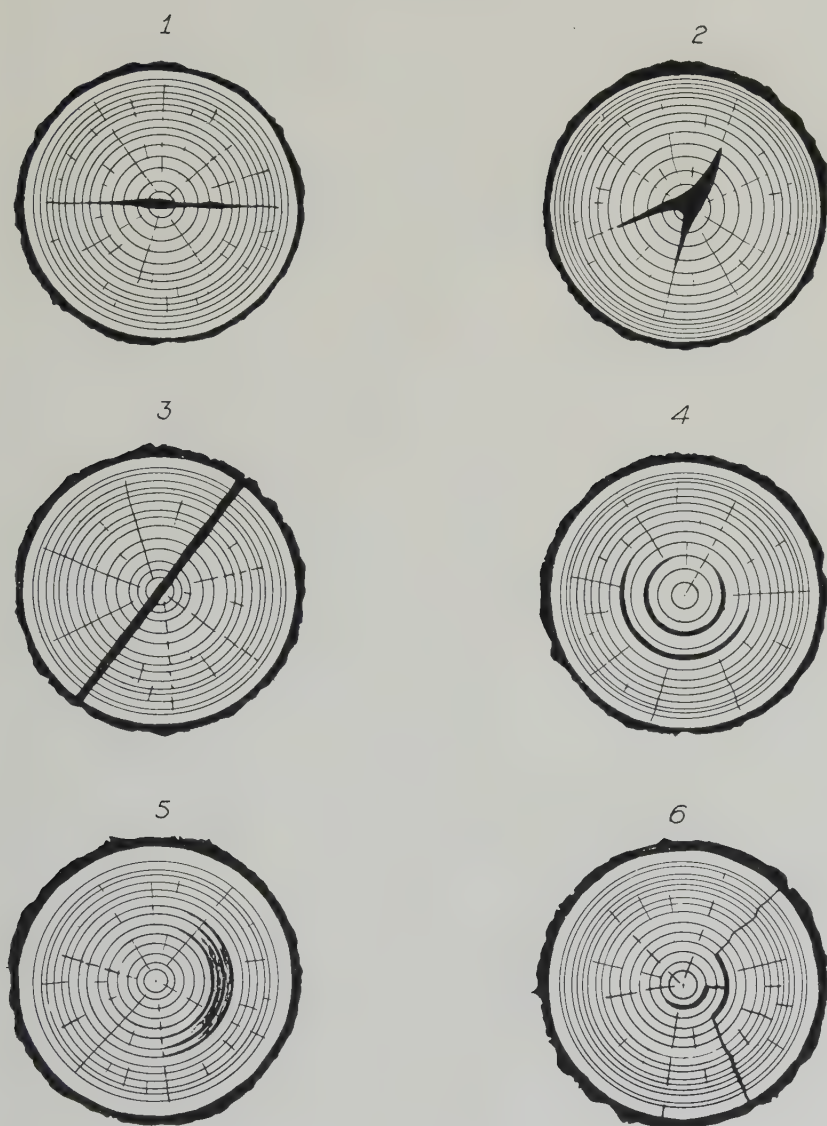


FIG. 9—DIAGRAM OF PIECE OF DOUGLAS FIR

Shakes, Splits, and Checks

Shake is the condition produced in lumber when two or more annual rings separate, forming a gap (see plate 20). If the gap is narrow, it is often filled with resin, or pitch, when it is known as a *pitch seam* or *pitch shake*. When not filled with pitch, shakes are classified as *through shake* or *ring shake*. In a piece of lumber a "through shake" is one that extends through the piece, or is connected from side to side, or from end to end of the piece. A "ring shake" occurs where an annual ring is severed or partly separated from another. Usually the term "ring-shake" is used only in referring to logs or timbers. Shakes most frequently are caused by the action of wind on a tree. They may be caused by the tree tilting over as a result of disturbance of the root system, and in rare cases by the action of severe frost.



HWE

FIG. 10—DIAGRAM OF SHAKES, CHECKS, AND SPLITS WHICH MAY OCCUR IN SOFTWOODS

1. Diagonal Open-heart Check
2. Compound Open-heart Check
3. Straight Split (through heart)
4. Ring Shake.
5. Pitch Seams
6. Compound Shake and Check

Splits are usually a result of shock sustained when the tree is being felled. They may sometimes occur as a result of snow or ice injury. Branches may be broken off as a result of the weight of snow upon them, with resultant fractures in the trunk. Splits may also occur as a result of frost injury.

Frost cracks are common to all species in cold climates, but on account of the greater uniformity of the cell structure of conifers are less common in the conifers or softwoods than in the hardwoods. Large frost cracks are usually found only at the base of a tree, rarely more than three feet from the ground. They are more frequent in old, stout trees of large crown, and in very young stands are altogether absent.

Trees on wet sites are said to be most liable to split from this cause. Frost cracks are most frequent between two roots or in the collars between two root-spurs. The cracks are generally apparent as radial splits of varying size near the butts of trees, but may appear in the shape of ring-shakes in which the thin-walled spring-wood cells have been ruptured. Various theories have been put forward to explain why frost cracks occur. Mayr⁶ states that during an unusually cold spell, owing to the low conductivity of wood, the outer rings attain a low temperature, while the inner rings lag behind in losing their heat. The outer rings contract in their periphery more than the inner rings, producing tensile stresses which result in radial failure across the grain. It is doubtful whether wind by causing the tree to sway is ever a cause of butt cracks in forest species, but it may have a cumulative effect in widening cracks that have formed as a result of frost.

Checks occur when the logs are lying in the woods, in seasoning, or, in the case of old, overmature trees, in the standing tree. In isolated cases they may be caused by the strong action of the sun on young trees when the bark is thin, but such checks are generally superficial or confined to the sapwood. They usually take the form of narrow, radial splits. They may be microscopically small, or may be measured in inches. In the great majority of cases checks are due to unequal shrinkage stresses caused by too rapid or uneven drying. They are radial because they originate at the medullary rays, the junction of rays and vertical tracheids being the place where shrinkage stresses are most likely to be unequal. The splitting due to shrinkage stresses may deviate from the radial direction and spread along adjacent rings, producing shake. In this way check and shake may sometimes occur together during the drying-out process. Such defects are obviously a source of weakness.

Figure 10 (page 23) shows graphically examples of checks and shakes which may occur in timber.

Resin

Resin, sometimes called pitch or gum, is an important consideration in the grading of softwood lumber, because of the frequency with which it occurs. Resin, as found in green lumber, is a thick, viscid, and generally brownish fluid. It is not a chemical compound, but a mixture of many obscure elements, among which turpentine is predominant. Resins are fusible, but not volatile, and when heated yield certain products which pass off as gases, leaving a crystalline residue behind. Resin is insoluble in water, but is soluble in alcohol and other organic solvents. It is inflammable, and the different resins have marked odour and taste.

⁶As quoted by Forsaith, C. C. Technology of New York State Timbers, 1926.

The resins of softwoods vary somewhat in appearance and properties. That of Douglas fir and spruce may be of various shades and colours, from a greyish-white to a nut-brown. It may be very thick or of a thin consistency. The resin of the true firs (*Abies*) is usually thin and of a yellowish colour. The various lighter-coloured resins often darken in colour on exposure to the atmosphere, through a process of oxidation. The resin of Western hemlock, when it is found, is of a dark-brown colour and usually thin. These remarks apply to resin in wood in an unseasoned or green condition. Kiln-drying crystallizes or hardens resin in wood, and deepens its colour, while prolonged air-seasoning has a similar, though less marked, effect.

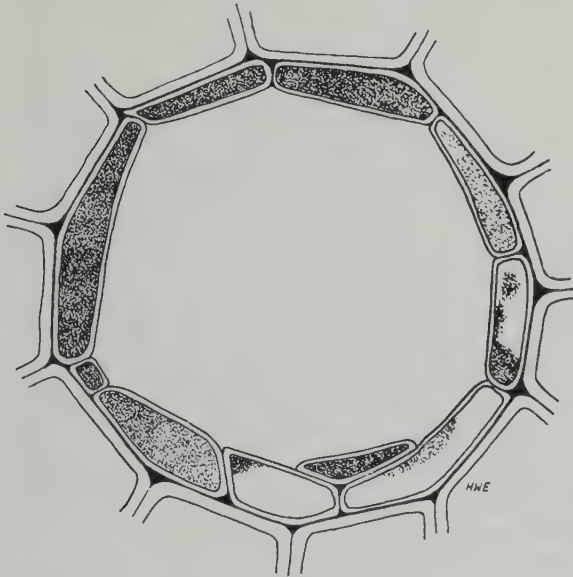


FIG. 11—DIAGRAM OF A
RESIN DUCT AS SEEN IN
CROSS-SECTION
(greatly enlarged)

The small, thin-walled cells surrounding the duct are parenchymatous cells in which the resin is manufactured.

Such a duct appears on a freshly cut, smooth cross-section of a board of pine, Douglas fir, spruce, or larch, as a small whitish or yellowish dot, sometimes as large as a pin-head, but usually smaller.

(See text.)

Woods which contain much oil or resin, e.g., Douglas fir, Western larch, Western red cedar, yellow cedar, are generally durable (see page 91).

Resin may be found normally in cavities inside the wood (splits and shakes), in the medullary rays, or in certain vertically arranged elements, called (1) *resin ducts* and (2) *resin cells*.

Resin ducts are intercellular spaces, lined with special small cells (parenchyma), which manufacture the resin. Not only may these resin ducts extend vertically up and down the tree, but they may extend in a horizontal, radial direction as parts of medullary rays. Figure 11 illustrates a typical vertical resin duct.

Resin cells are parenchyma cells of the normal cell structure which contain resin, generally in scattered single cells or groups of cells. The resin duct, however, is commoner, and is the typical structure.

The arrangement and distribution of these resin ducts and resin cells is a feature of great assistance in the systematic identification of softwoods. The resin ducts of the pines can be clearly seen by the unaided eye on the cross-section of the wood, when it is cut with a sharp knife. The ducts of Western larch, Douglas fir, and the spruces are also visible to the unaided eye, though sometimes a magnifying glass is needed. On the other hand, Western hemlock, the true firs⁷ and the cedars have, normally no resin ducts.

⁷Trees belonging to the botanical genus *Abies*, often known as "balsam" or "larch."

Resin ducts, although not normally present, may be formed as a result of injury in Western hemlock, true fir, and Western red cedar; in fact, the wounding or weakening of any softwood tree is liable to cause the formation of *traumatic resin ducts* and the formation of abnormal quantities of resin at the region of injury. In the case of a split or shake, or a wound to the outer trunk, a flow of resin occurs from these various sources of supply to the affected parts. The resin seals up the wound, in much the same way as a scab forms over a wound in an animal, preventing the ingress of exterior disease agents such as insects and fungous spores, and permitting the wound to heal, until new wood and bark have grown over the exposed area. In the case of an interior shake or split, resin may collect in the pocket. Large pockets of this kind in Douglas fir on being tapped have been known to yield as much as 40 gallons of liquid resin. Such accumulations of resin in a tree are known as *pitch-seams* or *-shakes* and *pitch-pockets* according to the size and shape of the cavities. Pitch-seams or -shakes are openings in the grain following the outline of the annual rings, containing more or less pitch, either granulated or liquid. The name "pitch-pocket" is applied to larger cavities in the wood filled wholly or partially with pitch, or to lens-shaped openings or cracks containing pitch, crossing the annual rings.

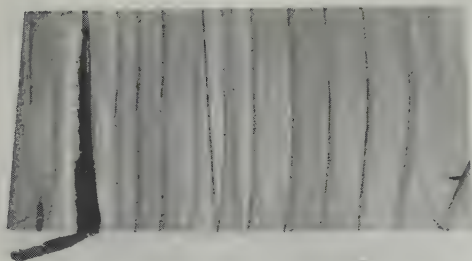
Grading rules provide for resin or pitch defects by specifying the size and number of the defects allowed in a board of each grade. Pitch-pockets are classified as *small*, *medium*, and *large*. In determining the seriousness of the pitch-pocket as a defect, its width and length are both considered. The wider the opening in the piece, the shorter it must be, or, vice versa, the narrower the opening the longer it may be in order to be admissible in the classification specified; in other words, pitch-pockets which present an equal area on the surface of a board are considered equal in their degrading effect. Pitch-pockets are "tight" or "closed" when they do not show an opening through the piece of lumber, and "open" when they show an opening through the piece. A pitch-pocket cut through its widest part and exposed on the surface of a piece is known as a *pitch blister* and consists of a wide, shallow opening, parallel with the grain of the wood, containing more or less pitch. Pitch blisters are classified as *small* and *standard*, according to their size.

Where an aggregation of abnormally resinous cells occurs, so that their resinous content can be plainly seen by the unaided eye, although the continuity of the grain is not disturbed, the defect is known as a *resin streak*, or pitch streak. These are classified as *small*, *medium*, or *standard*, according to their size. Resin streaks may be confused with "water-marks" or "water-soak" occasionally, when the wood is in an unseasoned or green condition.

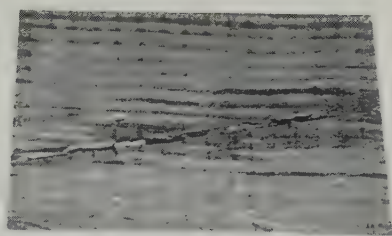
Plates 16 to 21 illustrate standard resin defects.

Resin in Various Softwood Species

No softwood species, even though it be normally non-resinous, is entirely exempt from pitch defects. Tree species in which resin ducts are part of the normal structure of the wood are, of course, liable to contain more resin than species which form resin ducts only as a result of injury. There is great variation in the resin content of individual trees, however, so that one tree belonging to a so-called non-resinous species may actually contain more resin in the shape of pitch-pockets than another tree of a so-called resinous species. The resin content of a tree varies not only with



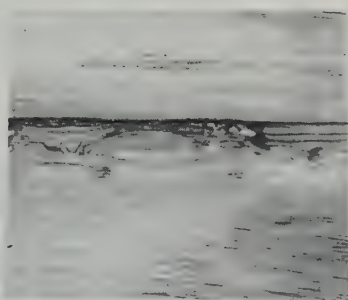
PL.16



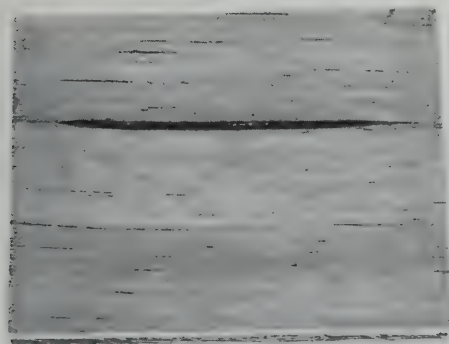
PL.19



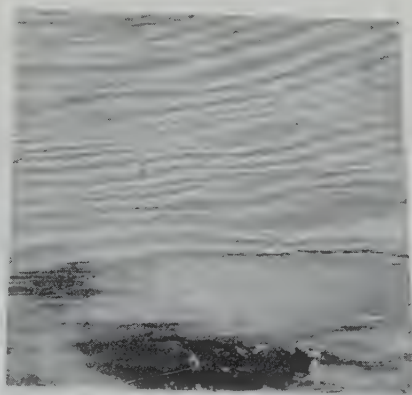
PL.17



PL.20



PL.18



PL.21

PLATE 16—A pitch shake in Western Hemlock
 PLATE 17—A pitch streak
 PLATE 18—A pitch pocket. (Somewhat reduced)
 PLATE 19—A pitch shake
 PLATE 20—A pitch seam
 PLATE 21—A pitch blister

the species, but with its age, habitat, degree of wounding present, and various other considerations, so that it is by no means advisable to assume that a certain tree specimen contains much or little resin because it belongs to this or that species.

Of British Columbia softwoods, the pines, Douglas fir, and Western larch are rated as resinous woods, while the spruces contain less resin, and Western hemlock, true fir, and the cedars are comparatively free from it.

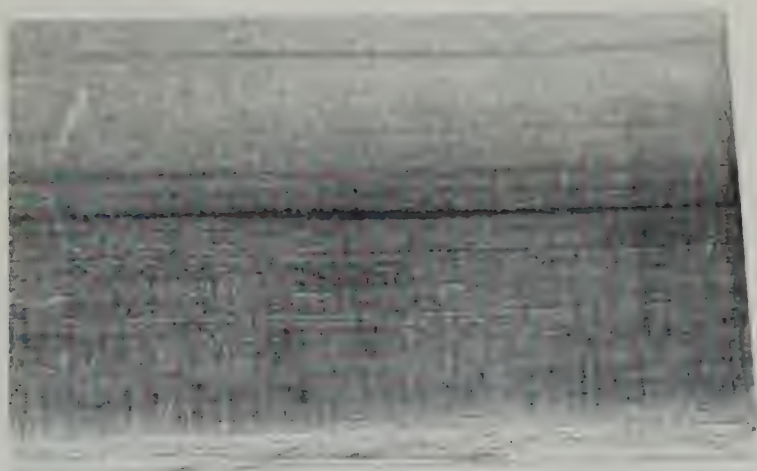
Resin in Western Red Cedar.—As in all softwoods, resin in one form or other occurs in cedar to a certain extent. Blazes or other wounds on cedar trunks sometimes exude a small quantity of resin, and scattered parenchyma cells containing resin abound in cedar; nevertheless, cedar is not considered a resinous wood, because aggregations of resin and pitch-pockets are seldom encountered in it, and resin ducts are not part of the normal structure of the wood. In place of resin the wood of cedar secretes an oil, which probably accounts for the great durability of this species, in spite of its soft structure.

In Western red cedar streaks occur which are similar in appearance to the resin streaks of resinous woods. Such streaks are due to concentrations of the cedar oil. They are no more a defect than "pitch streaks" in Douglas fir; in addition, the durability of such wood is increased, because of the large quantity of essential oil it contains.

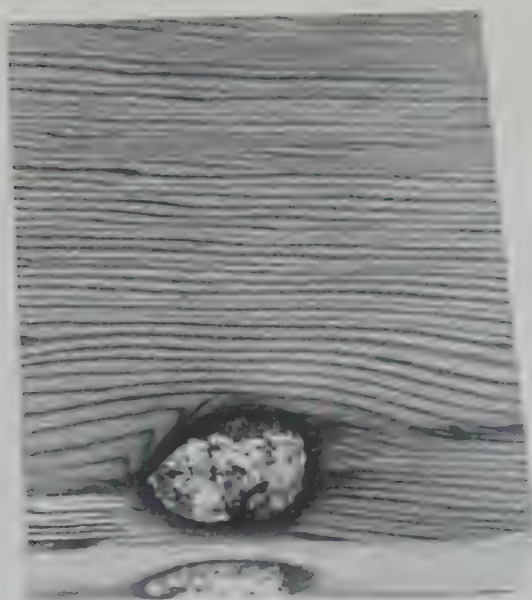
Resin in Western Hemlock.—The belief is widespread that resin or pitch cannot occur in Western hemlock, but it may occur in individual specimens of this species, as in any other British Columbia softwood species, resinous or non-resinous. However, it is not found in such large quantities in Western hemlock as it is, for example, in Douglas fir, and resin-pockets, as such, are only in rare instances found in hemlock. As a rule, the resin in such pockets is dark cinnamon-brown in colour, and unlike the resin which occurs in other native softwoods. (See Plate 16).

Small punctures made by birds in Western hemlock may be partially or wholly filled in by the reddish-brown resin peculiar to this wood. Portions of bark may also be found included in them. Such defects are commonly called *bird-pecks*, but are sometimes referred to as *bark-pockets*, where the holes are not apparent. Cavities or galleries produced by wood-boring grubs may be filled with bark or resin in the same manner.

Bird pecks generally resemble a carpet tack in shape, with the point towards the bark, and are usually accompanied by a discoloration extending along the grain, and, to a smaller extent, around the layers of growth. A tangential or slash-grained board, cut through the discoloration caused by a bird peck, produces what is commonly (though erroneously) referred to as a *mineral streak* or *mineral stain*. (See plate 25, page 120.) These little seams and pockets are quite common in Western hemlock, but may occur in other species. Because of their usually small size and their soundness they are not considered a defect in grading the wood.



PL.23



PL.24

PLATE 23—Oil streaks in Western Red Cedar

PLATE 24—Knot-hole in Douglas Fir filled with resin

CHAPTER II

DESCRIPTION OF BRITISH COLUMBIA SOFTWOODS

While a detailed description of the softwoods of British Columbia and a complete list of the uses to which they may be applied is outside the scope of this bulletin, nevertheless a brief description of these woods will be of value in facilitating study of the natural defects which occur in them.

On a botanical basis all native trees and shrubs may be readily separated into two great natural classes:—

- (1) *Gymnosperms* (with naked seeds).
- (2) *Angiosperms* (with enclosed seeds).

Fir, pine, spruce, larch, hemlock, cedar, and yew are gymnosperms, while maple, alder, willow, birch, hazel, dogwood, arbutus, cottonwood, poplar, ash, and chestnut are angiosperms.

The gymnosperms are variously referred to as “conifers,” “softwoods,” and “needle-leaved trees.” Each of these three terms is inaccurate because

- (i) all the gymnosperms are not conifers (cone-bearing)—yew, for example;
- (ii) many of the so-called “softwoods” (such as Douglas fir, Western larch, Western yew) are much harder than many so-called “hardwoods,” (such as cottonwood, willow, basswood);
- (iii) not all gymnosperms are needle-leaved (cedar, for example) and some of the so-called “broad-leaved” species or angiosperms have quite narrow leaves, e.g., willow.

The term “softwood” as applied to the gymnosperm group is more commonly used than any other, and perhaps is most applicable, because the gymnosperms on the whole contain softer wood than the angiosperms. Softwoods are valued for structural purposes because they combine a high degree of strength and stiffness with comparatively light weight and ease of manipulation.

The softwoods may be separated into two groups: (*a*) pine-like, and (*b*) cedar-like. Group (*a*) includes the pines, Douglas fir, the spruces, the larches, the true firs (or balsams), and the hemlocks. Group (*b*) includes the junipers and the cedars. All these are evergreens, except the larches, which cast their leaves every autumn.

Douglas Fir [*Pseudotsuga taxifolia* (Lambert) Britton]

With the exception of the giant sequoias of California, Douglas fir is the largest softwood tree that grows in the world. It ordinarily attains a height of 175 to 200 feet and a diameter of 3 to 6 feet. Frequently trees up to 250 feet and from 6 to 9 feet in diameter are encountered. It forms about 22 per cent of the total stand of saw-timber of the province, and is the best known and most important commercial species of British Columbia. It attains its maximum development in the lower coastal region of the province.

The bark varies a great deal in appearance. On young trees it is greyish-brown in colour, smooth, with light patches and resin blisters, resembling the bark of the true firs. On older trees it may be as much as 12 inches in thickness, is dark-brown in colour on the outside and reddish-brown when cut, and deeply furrowed longitudinally. It is a light-demanding species, so that the lower branches soon die and drop off, leaving from one-half to two-thirds of the trunk clear, and a large percentage of the wood free from knots. It is a healthy tree, and does not suffer from insect pests and fungous diseases to the same extent as its associated species. The sapwood is seldom over two inches wide.

The wood is generally referred to as "fir" by lumbermen. In the export trade of the Pacific United States it is frequently called "Oregon pine," or more simply "Oregon." As the same lumber is marketed in foreign countries as British Columbia fir, Douglas fir, and Oregon pine—the impression being thus conveyed that the three names denote different species, when in reality they designate only the one—this varied nomenclature is at times very inconvenient. However, the name "Oregon pine" is gradually being dropped and "Douglas fir" is taking its place.

The wood of Douglas fir varies considerably in grain and colour. Coarse-grained wood (wide rings) is often a reddish-brown colour (red fir) while fine-grained, slowly grown wood is a clear yellow-brown (yellow fir). Sometimes the red fir is referred to as "second-growth," while the yellow fir is called "first-growth," or "virgin-growth," fir. The botanical characters of trees furnishing these dissimilar qualities of wood are the same, and the two grades of wood may occasionally be obtained from the same tree. Where during the first stage of growth the diameter growth has been rapid, coarse-grained wood results, while the later, slower stages of growth produce fine-grained wood. This condition of growth is especially likely to occur in mixed stands where the young trees have had to make a fight for light, the species being intolerant of shade.

There is sharp demarcation between spring- and summer-wood in each growth-ring, which results in a pronounced figure in flat-grained stock. Resin ducts form part of the structure of the wood, and are usually visible to the unaided eye on a smoothly cut cross-section, appearing as whitish specks in the summer-wood. Exudations of resin at the ends and on the surfaces of lumber, and resin or pitch pockets are common. Under the microscope, Douglas fir can easily be distinguished from other commercial conifers by the spiral thickenings on the inner sides of the cell-walls, resembling the threads of a nut.

Douglas fir is strong, tough, straight-grained, durable in contact with the ground or when exposed to the weather, holds nails firmly, and is suitable for most uses to which lumber may be put. It is very suitable for large construction timbers, and can be used in various parts of house and building construction such as framing, rafters, joists, sills, posts, siding, window frames, sash, and interior trim. Owing to its hardness and density it is valuable for manufacture into edge-grain flooring. It seems to harden with age, and when polished and finished has a mar-resisting surface which makes it very suitable for doors, panels, beams, and other interior work. It takes stain well, and is easily finished. Of recent years a great deal of Douglas fir has been manufactured into three-ply for table tops, panelling, and furniture. When unseasoned, the wood has a characteristic, sweetish odour.

Its green rough weight is about 3,300 pounds per thousand feet board measure. When kiln-dried for rail shipment, it weighs about 2,500 pounds per thousand feet board measure rough.

Western Red Cedar (*Thuja plicata* Don)

This species is known locally as red cedar or simply "cedar." The name "red cedar" distinguishes it from yellow cedar, often called "yellow cypress."

Western red cedar forms about 22 per cent of the total stand of timber in British Columbia. It often attains a height of 175 feet, or more, and a basal diameter of 10 feet; the average size on the Coast, where it attains its best development, is 3 to 8 feet in diameter and 100 to 150 feet in height. It seldom grows in a pure stand, but is usually associated with Douglas fir, Western hemlock, true fir, or spruce. The competition of these other species seems to quicken its growth, and enables it to develop best its maximum form and quality. It is tolerant of shade, and does not cast its lower branches as readily as Douglas fir; therefore it contains more knots. The base is often conspicuously ridged and fluted, and the trunk tapers quickly at the base, so that the lumber content of a cedar tree is from one-third to one-fourth less than that of a Douglas fir of the same diameter at breast-height. The taper in young trees is not so pronounced, and these make excellent pole material. It is often difficult to estimate the merchantable contents of standing cedar, owing to the fact that old trees are often hollow in the butt and heart, especially in the mountain regions of the Interior. The bark is stringy in appearance, and very thin, so that the tree suffers much from the effects of forest fires, from which it rarely escapes without fatal injury.

The wood is of exceptionally light weight, soft, and not as strong as other softwoods. The heartwood varies considerably in colour, from a dark reddish-brown to a straw colour. The sapwood is usually not more than two inches in thickness and is light yellow or straw-coloured. Sometimes streaks or zones of alternating yellow and brown wood may be found in the same tree (see p. 9). There is decided contrast between summer- and spring-wood in each annual ring, so that the wood differs in this respect from yellow cedar. The summer-wood is thin and hard, but the spring-wood is very soft; and the transition between these two portions of the growth ring is abrupt.

Western red cedar is very easily worked, can be finished to a smooth surface with little effort, has a very even texture, is free from resin, takes and holds stains, paints, and enamels excellently, has superior gluing qualities, and is extremely durable. It is usually very straight-grained and splits so readily that Indians and woodsmen make split boards and "shakes" from it for building cabins; Indians also make their "dug-out" canoes from it, and many factory-built canoes are manufactured from Western red cedar. The wood has a distinctly aromatic odour, especially when unseasoned.

Cedar is a superior wood for a great many purposes in connection with house construction, except for rafters, joists, and finished flooring. Its freedom from pitch, its even texture, and attractive figure make it suitable for interior trim, panelling, and similar uses, where it is not subject to too much wear or abrasion. It is a good insulator and is suitable for sheathing, sub-floors, and roof-boarding. Owing to its weather-resisting qualities and its freedom from distortion of any kind when exposed to the weather, it is admirably adapted for use as siding and exterior finish. It will take and hold paint better than almost any other wood. Lately it has been used to some extent for railway ties. Its light weight gives it a considerable advantage over other western woods in the matter of freight charges when shipped long distances.

A large quantity of cedar is used annually for posts and poles, not only for local needs, but also for export. Cedar logs and lumber are shipped to Japan, where the wood is much in demand for light dimension material, panelling, etc., being highly valued by the Japanese on account of its similarity to their native cedar. Cedar logs of lower grades are used for the manufacture of roof shingles, where knots and other defects may be trimmed off and the clear portions utilized. British Columbia red cedar shingles have acquired a high reputation all over North America, being noted for their high grade, straight grain, lightness, and resistance to decay. Cedar shingles and lumber require careful kiln-drying, and high temperatures in the kiln sometimes cause the phenomena of "collapse" and "explosion," which may completely destroy the value of the wood for practical purposes. The moisture content of an unseasoned piece of cedar is often very unevenly distributed. Sometimes the end of a six-foot board will have a moisture content greatly in excess of that in the middle of the same board. The interior of a piece may show a moisture content three or four times that of the outside portion. When properly seasoned it shrinks very little, and does not subsequently change its shape appreciably by absorption of moisture from the atmosphere. Its variation in size due to changes in atmospheric conditions is only about one-half that of Douglas fir.

Yellow Cedar [*Chamaecyparis nothkatensis* (Lamb.) Spach]

Other names for this tree are British Columbia cypress, Alaska cypress, Sitka cypress, yellow cypress, and Alaska yellow cedar. There are not large quantities of the species in British Columbia, but it is a very valuable wood, being especially suitable for certain purposes.

Yellow cedar is commonly 75 to 80 feet in height and 2 to 4 feet in diameter. In dense stands it has drooping branches, few and distant from each other, with weeping, flat sprays, and has a slender, whip-like leader, which is too weak to stand erect and bends gracefully over. The trunk usually tapers rapidly, and it is not uncommon for the butts to be conspicuously fluted. The thin, stringy bark affords little protection against fire, which the tree rarely survives; it is dark, ashy-brown on the outside, and clear reddish-brown when broken.

The wood is appropriately called "yellow" because of its sulphur-yellow colour. It is similar in appearance and quality to Port Orford cedar, and can be used for practically any purpose for which the latter is used. In its green condition the wood has a pungent and distinctive odour, and Japanese loggers call it "stink wood." The odour may be detected even when the wood has been seasoned. This distinctive odour is repellent to moths and other insects, so that for clothes chests, glove boxes, etc., it is admirably adapted. Its natural odour becomes lessened in course of time. When the wood is soaked in water, drops of oil come to the surface of the wood, and oil may be obtained by distillation from both foliage and wood.

Yellow cedar is fine-grained, being slow-growing, and is about six pounds heavier per cubic foot than Western red cedar, with which it is often associated in the forest. It is also harder than Western red cedar. It is easily worked, does not splinter, and takes a beautiful polish. When properly seasoned, it will hold its shape without warping; the factors of shrinkage and expansion are lower than for any other British Columbia wood. Its freedom from shrinkage and warping, together with its remarkable durability, make it unsurpassed for shingles, outside finish, posts and poles, boat-building, and piling. It is said to be resistant to the attacks of marine borers, though not immune.

Considerable quantities of yellow cedar have, in the past, been cut and marketed with Western red cedar, because it was not thought worth while to separate the two. As large stands become more accessible, it will be uneconomical to ignore the high qualities of this wood by using it for inferior purposes or mixing it with inferior species. An important specialized use of the wood has been found in the manufacture of battery separators. It is porous and quite strong, the quantity of acetic acid it develops when used in batteries is small, and when properly manufactured and processed it is a good conductor, being similar in these respects to Port Orford cedar. At the present time Port Orford cedar is more widely used than any other wood for battery-separator construction, but the quantity of yellow cedar being used in this way is increasing.

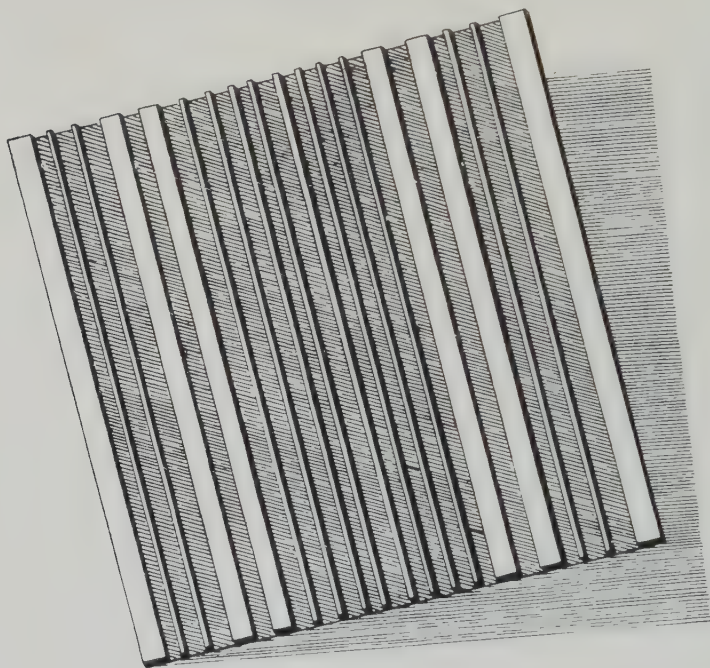


FIG. 12—A BATTERY SEPARATOR (about one-fourth actual size)

There is an increasing demand for yellow cedar for this purpose

Yellow cedar is also specially suited for the following purposes:—ships' hulls and ship construction generally, marine buoys, sash and door stock, high-grade furniture, caskets and coffins, columns (built up and turned), turning stock, borders for flower beds and garden work, block flooring, and outside doors for garages.

Spruce (*Picea* spp.)

Four species of spruce grow in British Columbia—Sitka spruce [*Picea sitchensis* (Bong.) Carr.]; Engelmann spruce [*Picea Engelmanni* (Parry) Engelmann]; white spruce [*Picea canadensis* (Mill.) B.S.P.]; and black spruce [*Picea mariana* (Mill.) B.S.P.]. There are estimated to be over 73,000,000,000 feet board measure of spruce in the province, representing nearly 21 per cent of the total stand. On the Coast there are 14,000,000,000

feet board measure, which is practically all Sitka spruce; in the Interior there are approximately 59,000,000,000 feet board measure, all of which is Engelmann spruce, excepting about 3,000,000,000 feet of black spruce and white spruce.¹

The woods of all the spruces are similar in their properties and structural characteristics. Sitka spruce, however, is the giant of its genus, and varies in size from 30 inches to 12 feet at the stump. The average size of logs is about 4 feet in diameter, compared with an average diameter of less than 1 foot in Eastern spruce logs. Sitka spruce may be 160 to 180 feet in height, while Engelmann spruce ranges from 80 to 100 feet in height and 18 to 36 inches in diameter. Engelmann spruce is the most important species in the interior of the province, comprising approximately 40 per cent of the stand. White spruce on a similar site grows to about the same size as Engelmann spruce, but in its northern habitat naturally it is smaller. What little white spruce is cut in British Columbia is graded with Engelmann spruce. Black spruce in British Columbia is a stunted tree, and is not an important forest species.

The bark of spruce is thin, dark purplish-brown or reddish-brown in colour, and early becomes scaly. The wood ranges in colour from a yellowish-white to a very light purple-yellow, the wood of sap and heart being much alike, excepting that the former does not have a purple tint. Spring-wood and summer-wood are not well defined, the transition from one to the other being gradual. The resin ducts are best seen on a smoothly cut end-section and are visible as small white dots; they are more numerous and are larger in Sitka than in Engelmann spruce. Pitch- or resin-pockets and seams are infrequently found. In Sitka spruce (seldom in Engelmann spruce), slight local distortions of the grain are common, caused by the action of certain parasitic fungi on the cambium layer. This result is sometimes referred to (erroneously) as "bear scratch" (see Plates 13 and 14, page 20). "Bird's-eye" in maple is caused in a similar way, but its appearance is different. Strength tests of aeroplane material have shown that such local distortions have no effect on the strength of spruce wood.

Sitka spruce is available in large, clear sizes and is comparatively free from knots. Where present they are generally black and loose. Engelmann spruce does not produce a large amount of clear lumber, but it provides a high percentage of high-class commons, the knots being small and largely of the red type. It more closely resembles white pine than any other British Columbia wood.

Spruce is suitable for most purposes for which other British Columbia softwoods are used. For large beams and structural timbers it is not as strong as Douglas fir, therefore not as suitable. Engelmann spruce is not as easily obtained in large sizes as Sitka spruce. The ability of Sitka spruce to resist deformation after shock, in conjunction with its lightness and its strength under tension, which allow it to be bent a great deal before it breaks, are qualities which have made it the ideal wood for aeroplane stock. It does not splinter when hit by a projectile, because of its long and tough fibre.

Engelmann and Sitka spruces are usually easy to work on account of their straight grain. Complaints are occasionally made that spruce "works hard." It has a long and tough fibre, and sharp knives should be used in machining it. If this precaution is observed, and the wood is allowed to dry thoroughly before machining, no difficulty should be experienced.

¹Whitford and Craig: Forests of British Columbia.

Both spruces hold nails well. They take paints, stains, varnishes, and enamels well and are good material for making sign-boards. Two coats of paint on spruce are said to be as good a finish as three coats on almost any other softwood.

Spruce is not so durable, when in contact with the soil or when exposed to the weather, as some other softwoods, such as Douglas fir, Western larch, and Western red cedar. It is less suitable for piling in salt water than are some other species, because of its susceptibility to teredo attacks.

Spruce can be made into various forms of rough and finished lumber, for which its cheapness, easy workability and lightness, ability to take paints or enamels well, freedom from warping and splitting, freedom from resin, and its smooth surface make it suitable. Spruce dimension timber is suitable for structural uses in houses, barns, and similar structures, for framing, studding, planking, and scantling. Its common grades of board and shiplap can be readily used for sheathing, roof-boards, and sub-flooring. It is used by sash and door factories for the manufacture of doors, windows, mouldings, frames, and interior finish, and is found to be a very satisfactory wood for these purposes. Spruce enjoys a preference in certain prairie markets where the trade is accustomed to its use.

The lower grades are often manufactured into box shooks for various purposes. When seasoned, spruce may be used for boxes which are to contain food products such as crackers, corn starch, butter, dried fruits, etc., because it is odourless and does not taint these substances. Eggs packed in boxes made from pine or other wood containing pitch are said to be tainted by such woods, but spruce may be used for such boxes without danger of tainting. It is used for lining refrigerators and kitchen cabinets for the same reason. Besides being odourless and tasteless when dry, it is lighter and softer than Douglas fir and Western hemlock, has a whiter and cleaner appearance, and does not soil as readily. Spruce is well adapted for other uses where the composite qualities of strength, lightness of weight, and freedom from odour and from splintering are required.

Spruce is the best American wood for making paper pulp, on account of its light colour, strength, toughness and length of fibre, and low resin content.

Western Hemlock [*Tsuga heterophylla* (Raf.) Sarg.]

Western hemlock is a product of the damp climate of the Pacific Northwest. With abundant atmospheric and soil moisture it thrives on poor, thin soils, and with any exposure, but best on deep, porous, moist soils.² Among the trees of the province, it is one of those most tolerant of shade, and its ability to endure shade often results in the establishment of Western hemlock reproduction to the almost complete exclusion of other species.

It grows to a height of 125 to 160 feet, and a diameter of 2 to 5 feet, though its diameter seldom exceeds 3 feet. When growing in dense stands its trunk, little tapered, is clear of branches and straight up to 50 or even to 70 feet, but there is great variation in the growth of the species. It does not produce heavy yields as compared with Douglas fir and Western red cedar, and 50,000 feet board measure per acre is a high yield.

Western hemlock forms about 24 per cent of the merchantable stand on the Coast, and about 9 per cent of that in the Interior; of the entire merchantable stand of the province it constitutes over 18 per cent. A large part of the annual cut is now absorbed by the pulp-mills which have been established on the Coast of recent years.

²Sudworth: Forest Trees of the Pacific Slope.

The bark of a mature Western hemlock is usually from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches thick, hard and deeply furrowed, and has a distinctive, clear, chocolate-red colour underneath the outer layers. It has a high tannin content. Lumbermen sometimes differentiate between "black" and "white" hemlock, based upon the colour of the bark. The white-barked hemlock (greyish in colour) is said to be usually healthier and freer from defects.³

In the woods, Western hemlock is susceptible to fungous and insect attack. When put into use in exposed situations it is liable to attacks from wood-destroying fungi, which fact may be due in part to the absence of resins or protecting oils in the wood and to the high moisture content of green hemlock. After it has been seasoned it will absorb moisture readily from the air, unless stored under cover. When green, Western hemlock has a sour and distinctive odour, which is not noticeable when the wood is dry. (See plate 39 on page 125, and plate 46 on page 126.)

For a long time Western hemlock endured the handicap of a bad reputation, inherited from Eastern hemlock; but it differs greatly in its properties from the latter, and is now recognized as one of the best Canadian woods for general purposes. For a number of purposes Western hemlock has been sold and used interchangeably with Douglas fir and Sitka spruce. It is considerably lighter in colour than Douglas fir, but may quite closely resemble spruce. It is hard and strong, and compares favourably in these latter respects with Douglas fir. It takes a good stain and polish, is light in weight, and is free from pitch-pockets. It also holds nails well. For flooring, panelling, doors, and other interior woodwork, Western hemlock ranks with Douglas fir in suitability and appearance, and its use for these purposes has increased greatly during recent years. A great deal of Western hemlock lumber, both dressed and rough, is now finding its way to European markets, and hemlock squares have been a staple export to Japan for several years.

True Fir (*Abies* spp.)

There are three species of *Abies*, or "true fir," in British Columbia—*Abies grandis* Lindley, *Abies amabilis* (Dougl.) Forbes, and *Abies lasiocarpa* (Hook.) Nuttall. Together they comprise about 10 per cent of the total stand of the Province.

In the forest the various species of true fir appear very similar. The crowns are dense, pyramidal in shape, with green, shiny foliage. The trunks are usually tall and straight, with little or no butt swelling, except when growing in the open. The bark is thin, smooth, and unbroken on young trees, grey to brown in colour, marked with chalky patches and resin blisters. As the trees age, the bark becomes furrowed and darker in colour.

Lowland fir may attain, under favourable conditions, a diameter of 3 to 4 feet, and a height of 125 to 175 feet, but is usually from $1\frac{1}{2}$ to 3 feet in diameter and 80 to 125 feet high. It seldom grows in pure stands, but is usually mixed with Douglas fir, Western hemlock, spruce, and Western red cedar. It is less tolerant of shade than amabilis fir and grows to a greater height. In large trees the lower trunks are usually clear of branches.

Amabilis fir grows from 3 to 4 feet in diameter and from 100 to 125 feet in height, but is usually $1\frac{1}{2}$ to 3 feet in diameter and 75 to 110 feet high. Well-stocked stands of amabilis fir, mixed with other species, will yield as much as 30,000 to 50,000 feet board measure per acre.⁴

³ Whitford and Craig. Forests of British Columbia.

⁴ Whitford and Craig. Forests of British Columbia.

Alpine fir, as its name signifies, is a typical timber-line species, and is found at elevations of 2,000 to 7,000 feet. It is usually a small tree, but may be as much as 2 feet in diameter and 100 feet in height. Associated species are Douglas fir, lodgepole pine, limber pine, and white-barked pine. The branches are often persistent, so that the wood tends to be knotty. In the interior of the province it is usually marketed with Engelmann spruce.

The wood of the true firs varies in colour from light brown to light yellow. It somewhat resembles spruce in the lighter shades, but in the darker shades often cannot be distinguished from Western hemlock. It is soft and light in weight. Its strength factors are low in comparison with Douglas fir, Western hemlock, and Western larch, but compare favourably with those of Sitka spruce, Engelmann spruce, and Western red cedar. The spring-wood, soft and white, merges gradually into the narrow but conspicuously darker and harder summer-wood. The wood is without characteristic odour or taste, and it is fairly free from knots. Bark-pockets are frequently found. The true fir is susceptible to attack by wood-destroying fungi and insects.

Most of the cut is utilized in the manufacture of paper pulp. The wood is also suitable for box manufacture and for common lumber.

Lodgepole Pine (*Pinus contorta* Douglas var. *Murrayana* Engelm.)

This species is distributed generally throughout the province. The total stand is computed at about 12,000,000,000 feet board measure (about $3\frac{1}{2}$ per cent of the standing timber of the province), nearly all of which is to be found in the Interior. On the Coast this tree is short, scrubby, and has many thick branches, except where it occurs in very dense stands. In the Interior it attains better development, reaching a height of 50 to 100 feet and a diameter of 12 to 24 inches. In close stands the trunk may be straight and clear of branches for 30 to 60 feet. Its extreme hardness and ability to reproduce after forest fires has enabled it to spread over extensive areas in the Interior, where it may be found sometimes in exceedingly dense, slim, pole-like stands. Its earliest use was for Indian teepee poles, and lodgepole pine is its most appropriate and distinctive name. The commonest name given to it in the Interior is jack pine, but it is a distinct species from the jack pine (*Pinus Banksiana*) of the Prairie Provinces and Eastern Canada. Other names given to it are black pine, in the Interior, and jack pine and black, or scrub pine, on the Coast. Although dissimilar in appearance, the Coast and Interior types have been found to be the same species. Lodgepole pine is the only two-leaved pine which grows in British Columbia. On mature, typical trees the bark is about an inch thick, dark-brown in colour, and furrowed.

The wood is hard, not extremely strong, comparatively light, and usually straight-grained. It is practically tasteless, but has a resinous odour when green. On flat-grain surfaces numerous slight indentations may be seen which give the surface a dimpled or bird's-eye appearance. Engelmann spruce, with which this tree is often associated, is entirely without the dimpled or dappled grain. The heartwood is only slightly darker than the sapwood.

Lodgepole pine is at present not widely used for lumber, though it is increasing in favour. The comparatively small size of the tree renders the percentage of clears small, but the wood is satisfactory for all the uses of common lumber, and has been found to make good box stock. Lodge-

pole creosoted poles have recently been marketed extensively in competition with Western red cedar poles, especially in the Prairie Provinces. The wood is chiefly used for railway ties, mine-props, and poles. It offers possibilities for the manufacture of wood-pulp, but up to the present it has not been used extensively for this purpose.

Western White Pine (*Pinus monticola* Douglas)

This species occurs on Vancouver island, on the mainland coast, and in the southern interior of British Columbia. It is one of the finest woods in the province, but it forms less than one per cent of the total stand. It never occurs in pure stands, but in groups or single specimens, mixed with Douglas fir, Western red cedar, and Western hemlock, generally in positions where it can receive light.

When mature the tree is usually 2 to 3 feet in diameter, occasionally 4 feet, and 75 to 100 feet in height. The trunk is tall and straight, with little taper, and is generally clear for about two-thirds of its length. On young trees the bark is silvery-grey, thin, and smooth. On old trees it is purplish to brown in colour and broken into squarish sections about one inch in thickness. The inside of the bark is cinnamon-red in colour.

The wood is moderately light and soft, with pale reddish-yellow heart-wood and sapwood pale yellow to nearly white in colour. Its natural colour deepens upon exposure to sunlight. The grain, as a rule, is quite straight and compact, and its texture is smooth. There is little contrast between spring-wood and summer-wood, and the soft spring-wood merges very gradually into the slightly harder and darker summer-wood, so that the annual rings are not pronounced. The resin ducts are visible on a smoothly cut end-section usually without a lens. On a longitudinal surface they appear as very thin, straw-coloured or light-brown, parallel lines, running with the grain. The resin ducts are especially conspicuous in second-growth lumber (Record). The wood is practically tasteless, but has a slight, yet distinct, resinous odour.

Western white pine is suitable for the best kinds of finish and for general purposes. It is very similar in appearance and qualities to Eastern white pine (*Pinus Strobus*), and appears to be simply a variation of the Eastern species brought about by environment. It is easily worked, takes nails readily, and has low shrinkage and expansion properties, which adapt it exceptionally well for making patterns for foundry work and turnery. Carpenters and cabinet-makers like the wood on account of its moderate lightness and its workability, and sometimes refer to it as "white-wood." It finishes smoothly and easily, takes a high, satiny polish, and readily holds stains and varnishes, oil finishes, and paints. For general flooring purposes white pine is not eminently suited, because of its softness. It is used to some extent, however, for decking of pleasure yachts and launches, where appearance is the chief consideration.

Its uses are many and varied, and in house construction it is made into doors, interior trim and finish, and panelling. Considerable quantities are used in the manufacture of match-blocks. Boxes and crates consume much of the lower grades.

Blue and brown sap-stains frequently occur on Western white pine, especially in the early spring and autumn, but the defect is not so common in this wood as it is on Western yellow pine. For certain special purposes, like match stock and aeroplane stock, stained white pine is not accepted.

Western Yellow Pine (*Pinus ponderosa* Douglas)

This species has had a variety of names bestowed upon it, among which are British Columbia soft pine, Western soft pine, bull pine, yellow pine, red pine, and pitch pine. The pine associations are now attempting to standardize the name "Ponderosa pine."

In British Columbia its growth is confined to the drier regions of the southern part of the province, and it is estimated to comprise only a little more than one per cent of the total stand of saw-timber. It grows in open, park-like stands, usually mixed with Douglas fir, but sometimes alone, and generally comprises at least fifty per cent of the stand in which it occurs. It usually is straight, clear of branches, and has little taper. Its mature size in British Columbia is 18 to 40 inches in diameter and 60 to 100 feet in height. It has a very distinctive appearance, having a thick bark, marked by broad, shield-like, reddish-yellow plates. The bark is especially thick near the base of the tree, and thus affords protection against ground fires, which are of frequent occurrence in this forest type, owing to the ground-cover of grass. It is the only pine native to Western Canada which has its needles in bundles of three.

The wood is smooth in texture and finishes well. It is quite variable in colour; the general range is pale lemon to reddish-yellow, but sometimes it is so light as to closely resemble white pine. The sapwood is wide, and pale yellow to almost white in colour. Frequently numerous slight depressions are visible on the tangential surface of the wood, giving it a dimpled or "bird's-eye" appearance. This peculiarity, however, is not so noticeable as it is in lodgepole pine. Large resin ducts on a smooth cross-section are usually visible to the unaided eye. The distinct bands of summer-wood, particularly noticeable in the heartwood, serve to distinguish yellow pine from white pine.

Its general similarity in appearance and properties to white pine enable it to be used interchangeably with it for many purposes, such as interior or exterior finish—especially sash and door stock—and the manufacture of furniture and similar products. It is softer and lighter than Douglas fir or southern pine, and has a resinous odour, but is tasteless.

It holds nails well, and does not readily split. It is much in demand for fruit boxes; boxes made of Western yellow pine look well when the wood has aged, and are not readily discoloured or marred by handling. It is not extremely durable when exposed to the weather or in contact with the soil, but it takes paint well, and for siding and similar purposes is serviceable when painted.

Western yellow pine is very subject to blue and brown sap-stains, more so than Western white pine. These are most damaging in their effects in early spring and autumn. At these times all possible precautions should be taken to dry lumber which is being seasoned in the yards as rapidly as possible. (See plate 49, page 125.)

Serious losses in standing timber of this species have occurred through the attacks of bark-beetles.

Western Larch (*Larix occidentalis* Nutt.)

In the southern interior of the province, where it grows, this species is most commonly known as "tamarack." The name "larch" is often erroneously applied on the Coast to lumber cut from amabilis fir and lowland fir.

Western larch is frequently a large tree and ordinarily attains a height of 100 to 160 feet and a diameter of 2 to 4 feet. It comprises about one per cent of the total stand of saw-timber in the province. It is seldom found in pure stands, being usually mixed with lodgepole pine, Douglas fir, Engelmann spruce, alpine fir, and Western hemlock. It is very intolerant of shade, even when young, and thus does not succeed in competition with dense reproduction of lodgepole pine, Douglas fir, and spruce. Where it has sufficient light and moisture it grows rapidly. The trunk is straight, and above the root-swelling tapers very gradually. The crown is usually short, leaving in the larger trees a length of 60 to 100 feet clear of branches. The mature tree has a thick, deeply furrowed, reddish-brown, flaky bark, especially thick near the base, which enables it to withstand forest fires while its neighbours of other species are being destroyed. Young trees have thin, scaly, greyish-brown bark. Western larch is the only conifer in British Columbia that is deciduous, that is, which casts its needles every autumn.

The sapwood is a light-brown or straw colour, and seldom more than an inch thick. The heartwood is of a bright reddish-brown colour, usually of high density (as indicated by the quantity of summer-wood present), of rapid growth, and has clearly defined annual rings. In appearance the wood somewhat resembles southern longleaf pine. It can be distinguished from the hard pines by the smaller size of its resin ducts, which are seldom visible to the unaided eye on a cross-section. It is much superior to the wood of Eastern larch in texture, strength, and hardness. It is one of the most durable of the commercial woods of British Columbia, rating with Douglas fir in this respect, and being surpassed only by Western red cedar and yellow cedar. It has no conspicuous odour.

Flat-grain boards display a very attractive figure, and the wood makes an excellent edge-grain flooring, being harder and heavier than Douglas fir, though inclined to shrink and warp if it is not properly seasoned, and to split under nails. Carpenters sometimes discriminate against it on account of its heaviness and hardness, which make it less workable than some other woods. Western larch varies a great deal in quality, however, and from some districts is considerably softer, lighter, and of slower growth than from other districts. Resin is plentiful in this wood, exuding sometimes during manufacture and "gumming up" the saw. It generally surfaces well.

Mechanical strength tests have proved it to be in some respects a stronger wood than Douglas fir. Its strength in impact bending makes it very suitable where the wood is to endure sudden heavy jolts and strains, as in the keels and hulls of ships, railway ties, bridge timbers, wharf timbers, and other heavy construction. It is especially durable in contact with the ground or where exposed to the weather; and this quality makes it very suitable for use in bridges and wharves, docks, tramways, culverts, warehouses, factories, snow-sheds, boat- and shipbuilding, car construction, and similar work. A drawback to the better utilization of Western larch for structural timber is the fact that in the southern Interior logs are seldom cut over 16 feet in length, and long timbers are hard to obtain. If longer logs were cut, probably a more lucrative market could be obtained. Western larch is also very suitable for use as piling. For railway ties it is considered superior to any other Western species, because of its durability, strength, and hardness (which latter quality enables it to withstand rail cutting).

Western Yew (*Taxus brevifolia* Nuttall)

The yew, as it grows in British Columbia, is frequently a short bush rather than a tree, but often develops to tree size with a trunk which may be a foot in diameter. It has been known to reach a height of 75 feet, and a diameter of 18 to 30 inches, but this is a rare occurrence.

This species never grows in large stands; sometimes it occurs as a group of several trees, more often singly. It occurs in the coastal belt as far north as the latitude of Prince Rupert, also in the southern and eastern portions of the province. The yew is extremely tolerant of shade, but requires abundant moisture. The rate of growth is slow, but it lives to a good age, the largest trees being three hundred to three hundred and seventy-five years old. Though not a true conifer or cone-bearer, the yew is generally grouped with the conifers for convenience, as it resembles them more closely than the hardwoods, or broad-leaved trees. The fruit is a bright red berry, one-quarter inch to one-half inch in diameter, contains a single seed, and is greatly favoured by birds for food, which accounts for the scattered propagation of the tree in various parts of the province. The trunks are often ridged and fluted, in a similar way to the butts of Western red cedar. The branches droop, also, as in cedar. The bark is stringy like the bark of cedar, but has a bluish or purplish tinge, and is thinner than cedar bark, being rarely over one-quarter of an inch in thickness.

The heartwood of yew is fine-grained, and varies in colour from clear rose-red to dark reddish-brown, while the sapwood is pale lemon in colour. The wood seasons well, is of fine texture, dense, hard, and strong, and is extremely durable. Fence-posts of yew will often last beyond the lifetime of their owners. It is well figured and occasionally produces a burl, which is unexcelled in beauty by any other wood and is very valuable.

Western yew is the heaviest and hardest of the western softwoods, or conifers, and in some respects is the strongest. It is not extremely strong when subject to sudden jars or shocks, but for endurance and toughness, combined with resiliency under an increasing load, it easily surpasses any coniferous wood native to North America. It has for centuries been much valued for making bows, canoe paddles, and spear shafts. It is suitable for hand-turned goods and for cabinet-work, and is particularly suitable for making high-class chairs; antique furniture of former periods is frequently found to have been made from yew.

Perhaps the most practical method of collecting the wood at the present time is by using Indian labour. It does not seem to find a regular place in lumber stocks anywhere, being mixed with other lumber as soon as it reaches the sawmill.

Identification of British Columbia Softwoods

Ability to identify woods by visual inspection is to be attained mainly by practice in handling or examining them. A man who has been used solely to the lumber of one region will often have difficulty in identifying the woods of another lumber region. Even to an experienced millman, some local species may very easily be confused with others, especially in cases of unusual growth. Western hemlock and true fir, Western hemlock and Douglas fir, true fir and spruce, spruce and Western hemlock, Douglas fir and Western larch, spruce and Douglas fir, Western white pine and Western yellow pine, are often quite easy to mistake one for the other, and in some cases a microscopic examination of the structure of the wood is necessary to determine the species.

It is convenient to carry a hand-lens when one is likely to be called upon to identify a piece of wood, although even a hand-lens is not always sufficient and the microscope has to be resorted to in extreme cases. By means of a hand-lens an examination of the end or cross-section of a piece of wood can be made and the presence or absence of resin ducts determined. To do this a very smooth surface is necessary, since resin ducts are often quite small and may be seen only with difficulty. A good plan is to moisten the surface, after cutting with a sharp knife; this shows up the ducts more plainly.

Western white pine, Western yellow pine, and lodgepole pine have quite large resin ducts which are plainly visible without a lens. The vertical resin ducts appear on the end-section as little, yellowish dots, and on the tangential or flat-grain surface as fine lines or scratches, light or dark in colour. They are numerous and well distributed. The colour of the wood of yellow pine, as its name implies, is generally darker than that of white pine. In Western yellow pine, especially in the heartwood, there are distinct alternate bands of summer- and spring-wood and the transition from one to the other is abrupt. In Western white pine the spring-wood gradually merges into the summer-wood and the line of demarcation between the two is indistinct. Lodgepole pine wood can almost invariably be identified by the "pebbly" or "dimpled" grain on the tangential surface. The same peculiarity is found occasionally in Western yellow pine, but it is not as characteristic or as marked as in lodgepole pine. The wood of the pines, especially when green, has a characteristic, pine-like odour.

In Western larch the resin ducts can sometimes be seen with the unaided eye, but they are small, inconspicuous, and scattered. The wood of Western larch is mostly hard and heavy, and distinctly reddish in colour, but it varies a great deal. The texture of the wood may be described as "flinty," contrasted with Douglas fir, which is softer and more workable.

The wood of spruce has a fine, satiny sheen or lustre. Engelmann spruce is generally white or very light in colour, while Sitka spruce tends to be pinkish. The resin ducts of Engelmann spruce are generally small and scarcely visible without the aid of a lens, while the ducts of Sitka spruce are larger and generally visible to the unaided eye. The wood of Sitka spruce often greatly resembles that of Douglas fir. In case of doubt it can be distinguished on the basis of the character of the resin ducts, which in Sitka spruce are much larger and more prominent than in Douglas fir. Spruce and true fir may be differentiated by the presence of resin ducts on a smoothly cut cross-section in the former, and by their absence in the latter.

The resin ducts of Douglas fir are widely variable in size. They may be visible to the unaided eye or they may be hard to see, even with a lens. They are seldom numerous or well distributed. Douglas fir can be distinguished from the pines by its absence of pine-like odour, and usually by absence of the narrow lines of the resin ducts on tangential and radial surfaces. Its colour is not so lively or satiny as that of spruce. When compared with western hemlock its colour is reddish and more pronounced than that of the latter. Douglas fir is of two general classes, namely, (1) the so-called yellow fir—fine-grained, slow-growth, light and soft and easy to work, in colour a pale reddish-yellow—and (2) the variety called "red fir"—coarse-grained, fast-growth ("second-growth"), with spring-wood open in texture, and summer-wood hard and dense, in colour rather reddish.

Resin ducts (both vertical and horizontal) are normally absent in Western hemlock, true fir, Western red cedar, and yellow cedar, so that these species cannot be distinguished from each other on the basis of resin ducts. Ducts may, however, occur in these species as a result of injury, in which event they may usually be found in the form of a compact arc on the cross-section, in place of the scattered arrangement typical of the normal resin duct. Yellow cedar is at once distinguishable by its sulphur-yellow colour and its pungent odour. It is invariably a slow-growing wood of fine grain. Western red cedar is distinguishable by its softness, generally reddish-brown colour, and distinctly aromatic odour. Western hemlock and true fir very often defy the most practised eye to tell them apart. The characteristic colour of Western hemlock is light yellow, lighter usually than Douglas fir, and often with slight purplish streaks running with the grain. Small bark-pockets and bird-pecks, resembling in shape and size a carpet tack, or the head of a carpet tack, are often found in Western hemlock. True fir does not have so many of these bird-peck defects, but it may often have the purplish tinge.

Resin ducts are readily formed in Western hemlock as a result of injury; when, occasionally, there is found in a piece of hemlock a shake or seam filled with a brownish resin, this should not be looked upon as an extraordinary occurrence.

The wood of yew is very heavy and hard. The heartwood varies in colour from rose-red to dark reddish-brown, while the sapwood is pale lemon in colour.

Occurrence of Hybrid Trees

When it has not been easy to identify a particular piece of lumber, because it differs in appearance from any of the local commercial species, or may even appear to resemble two of those species at the same time, there has been a tendency to suppose that such a doubtful specimen came from a "bastard" or "hybrid" tree. The Forest Products Laboratory has been asked from time to time whether or not it is possible for a so-called "bastard" tree specimen to be produced, which would be a cross or hybrid between two trees of different genera and represent some of the physical characteristics of both. It has been suggested, for example, that a hybrid between Sitka spruce and Western hemlock could be produced naturally, the wood of which would partly resemble spruce and partly hemlock. It has been further asserted that some of the growth rings of such a hybrid tree would contain spruce wood, while other rings contained hemlock wood.

There is often variation of form and structure within a species (*species* is a subdivision of the botanical subdivision *genus*) owing to the fact that its members may grow over an extensive area and in different parts of that area be subject to many differences of climate, soil, and surroundings. In such cases, if other members of the species can be found showing the stages by which the variations have occurred, members having definite differences are called *varieties* of the same species. If no intermediate stages can be found, the two different plants are placed in separate *sub-species*.

Examples of this change in form and structure within a species may be witnessed in British Columbia in the differences between the lodgepole pine of the Rocky mountains and that of the Coast district.

In the southern Interior the "bull pine" is thick of crown, very conical in shape, has dark, thick, deeply furrowed bark, and wide-ringed, dense wood. The "yellow pine" has a thin, yellow bark, soft, close-grained outer

wood, and open, flat crown. In addition, the inner portion of the wood of an old "yellow pine," with varying distances out from the pith, shows all the indications of white pine structure. Both trees are of the same species, that is, Western yellow pine.

Species and varieties of a species propagate their kind, in the case of coniferous trees (including hemlock, spruce, larch, fir, and pine), by cross-fertilization or self-fertilization (usually the latter). Occasionally crosses between two closely related species of the same genera will occur, as in the case of crosses between Engelmann spruce and white spruce which have been found in the Banff region. In this case, as in other cases of crossing of tree species, the wood is quite uniform in texture and appearance; the systematic botanical structure of any tree is always uniform.

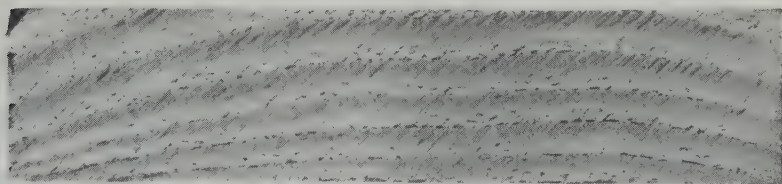


PLATE 26—"Compression wood" in Sitka Spruce

Hybridization, even between closely related species, is a very uncommon occurrence in nature. It stands to reason that this is so; otherwise the various species of both plants and animals would be so numerous as to defy any classification of both genera and species. Natural crosses *between members of different genera* (as, for example, spruce, hemlock, pine) have never been known to occur in the woods. If a hybrid of two genera like spruce and hemlock did occur, there is not much likelihood that it would be a healthy specimen. It would also probably be sterile and unable to reproduce itself.

In spruce, Douglas fir, Western hemlock, and Western larch, a board may be occasionally encountered with a very high percentage of summer-wood in the annual rings. Sometimes this percentage may be as much as 90 per cent of the total wood in the annual ring. In rings containing such an extreme quantity of summer-wood the wood is sometimes referred to as "compression-wood," especially where the rings are irregular in shape or variable in width. This compression-wood is said to be caused by the tree leaning or tilting in a certain direction, compressing and distorting the growth on the leaning side. Such wood is usually weak, and when it fails does so with a brashy break. Pieces containing this high percentage of summer-wood differ considerably in appearance from normal wood and cause confusion in identification. Unusual boards of this kind should not be termed "bastard" boards, with the idea that the tree from which they came was a cross or hybrid between two parent trees.

"Red" and "yellow" fir may be found not only in separate trees, but in one and the same tree. It frequently happens that in the first stage of growth, lasting 50 to 100 years or more, diametral growth is rapid, producing coarse-grained wood, while the later stages of growth are slower and produce fine-grained wood. In cases where "red" fir is in the stage of changing over into "yellow" fir the differentiation is often carried a step further, and the wood from this part of the tree called "bastard fir." The botanical characters of trees furnishing these dissimilar qualities of wood are the same, and there is no foundation for the popular belief that these two kinds of wood come from two different species of tree, nor for the belief that trees containing both kinds of wood are a hybrid or cross between two species. Variations in colour, texture, and density within a species or in an individual tree should not be attributed to hybridization.

CHAPTER III

WOOD-INHABITING FUNGI

Decay is the most important and serious defect to be found in both standing and manufactured timber. Its seriousness is emphasized by the fact that the progress of decay in wood is cumulative in effect, so that perfectly clear specimens may in course of time become entirely disintegrated, as long as physical conditions are satisfactory to the rot-producing organisms.

Decay, dote, or rot in wood is caused by low forms of plant life called *fungi*. The typical green plant uses its chlorophyll to build up carbohydrate and proteid food supplies from the raw mineral materials and water of the soil and the gases derived from the atmosphere, but fungi are not green plants and have no chlorophyll. With rare exceptions, plants which have no chlorophyll are, like animals, dependent upon organic food already in a manufactured state. They may obtain this food either from living plants or animals—in which case they are said to be “parasites”—or from dead animal or vegetable matter—in which case they are said to be “saprophytes.” Many wood-destroying fungi may be termed “saprophytic” when they are considered as living upon and obtaining nourishment from wood; when their relation to living trees is considered they may be termed “parasitic.”¹

Wood-destroying fungi occur characteristically as long, branching threads or filaments, generally colourless, known as *hyphae*, which grow in and through the wood substance. Collectively, the hyphae are known as *mycelium*: this may be considered the vegetative (as contrasted with the reproductive) portion of the fungous plant. When the growth is prolific, the hyphae may form a matted tissue of mycelium on the surface of the wood in which the fungus is growing. The greater portion of the plant is, however, within the wood substance.

After a certain period of development the mycelium may produce on the surface of the wood *sporophores*, or *fruiting bodies*, of which the conch or bracket form, familiar to the woodsman, is an example. These fruiting bodies are the means by which the fungus normally reproduces itself. They vary greatly in shape and size from the large conch or bracket to leathery, flat forms, or small gelatinous growths which wither up when dry, or, in the case of blue stain, tiny black bodies (*perithecia*), which are hardly discernible to the naked eye. Those fruiting bodies which take the form of conchs, brackets, shelves, and crusts usually have numerous small pores on their lower surfaces, which are the orifices of spore tubes; e.g. *Polyporus*, *Poria*, *Merulius*, *Trametes*, and *Fomes*. In some species, as in *Stereum*, the lower surfaces are smooth. In *Coniophora*, whose fruiting body takes the form of a flat crust, the outer surface is frequently warted. Other genera have mushroom-like gills on their lower sides, e.g. *Schizophyllum*, *Lentinus*, *Lenzites*. *Echinodontium* has distinct teeth or spines on its lower surface.

¹On this point cf. Hartig, R., *Diseases of Trees* (translation revised and edited by H. Marshall Ward, London, 1894), pp. 46-7, and H. Marshall Ward's footnotes in the same work, p. 47.

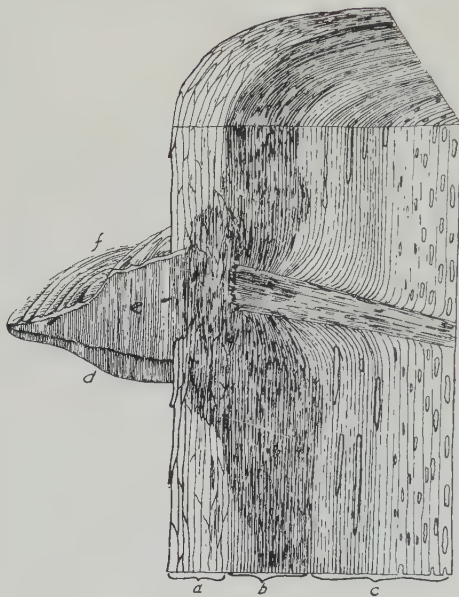


FIG. 13

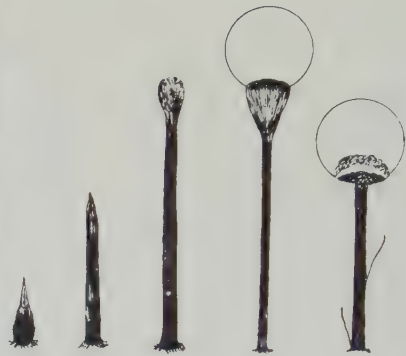


FIG. 14

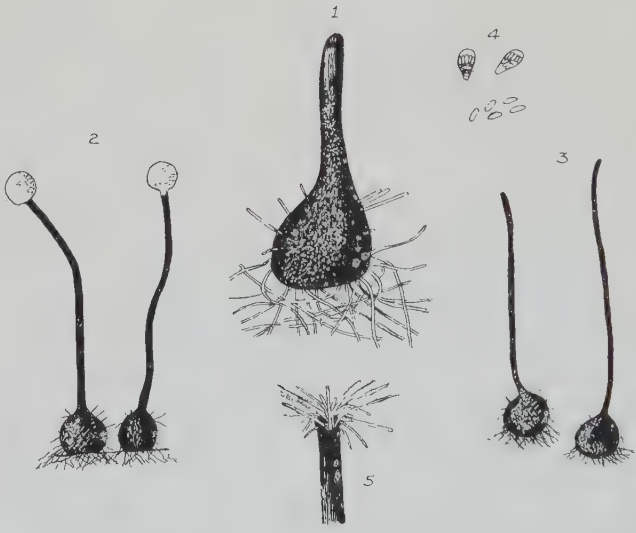


FIG. 15



FIG. 16

(For legends see opposite page)

FIG. 13—SECTION THROUGH A SPOROPHORE OF *Trametes Pini* GROWING IN A WESTERN CONIFER. (Greatly reduced.)

These frequently grow on those parts of the trunk where a branch has been broken off.

- (a) Bark.
- (b) Sapwood. The dark-shaded portion represents the resin-soaked condition of wood in the vicinity of the sporophore. Such wood when cut into lumber bears a very resinous appearance and is described as having "pitch" or "resin streaks."
- (c) Wood in the typical stage of decay. Note the oval-shaped pits (partly filled with white mycelium) produced by this type of rot.
- (d) Canals or pores in which the spores are produced. Millions of spores may be produced in one season from a single sporophore.
- (e) Older spore tubes which have become filled up with mycelium.
- (f) Upper surface of sporophore. Note the annual zones of growth.

(After Hartig)

FIG. 14—FRUITING BODY OF *Graphium* sp. (greatly enlarged)

Graphium spp. are responsible for most of the brown sap-stain of pines. They sometimes produce a black stain. The fruiting bodies are brown to black in colour, 1 to 3 mm. high, upright, cylindrical, occasionally branched, and bear at their tips globules composed of masses of spores.

(After Münch)

FIG. 15—FRUITING BODIES OF A BLUE-STAIN FUNGUS (*Ceratostomella pilifera* Fries) (greatly enlarged)

They are approximately 1/25 of an inch long and form, *en masse*, a dark, hairy covering on the end and tangential surfaces of stained sapwood. When well developed these growths are sometimes referred to by lumbermen as "whiskers."

1. Young fruiting body of the "blue-stain" fungus.
2. Mature fruiting bodies.
3. Normal fruiting bodies.
4. Spore sacs and spores.
5. Top of beak of fruiting body just after discharge of the spore mass.

(After Von Schrenk)

FIG. 16—TUFTS OF DOWNY MYCELIUM GROWING ON A PIECE OF LUMBER

Dry-rot and other wood-rotting fungi commonly begin to fruit in this fashion. After a time this mycelium may grow into a leathery layer seen as a patch on the surface of the wood. This is the mature fruiting body or sporophore.

Wood on which these woolly tufts are found growing should be removed from the lumber pile or the structure of which it forms a part immediately, because from it fungous infection will undoubtedly spread to adjacent timber.

In spite of differences in form and structure, the method of propagation is similar in all cases. From each fruiting body are expelled myriads of minute bodies known as *spores*, which are scattered and blown about by air currents until they come to rest. Some of these, when they find a suitable *nidus*, or place of germination, develop and form new growths of hyphae and mycelia. The function of the spore is therefore similar to that of a seed. As each fruiting body can produce in the course of a single season literally billions of these minute spores, and as they are very light and able to drift about in the air for a long time, it can be seen that at all times, but particularly in summer and autumn, the atmosphere contains abundance of spores, especially in the neighbourhood of lumber yards or in localities where there may be a quantity of decaying wood.

In addition to spores produced by fruiting bodies, spores are often produced directly by the mycelium. These spore forms may be borne on short stalks on the mycelial threads, when they are known as *conidiospores*, or the mycelium itself may break up into short cells (*oidiospores*), or specialized thick-walled cells (*chlamydospores*) may form within the mycelium. The last-mentioned kind of spore, on account of its thicker walls, is adapted to withstand unfavourable weather conditions; the two former kinds are usually thin-walled and very minute.

It will be seen, therefore, that the non-appearance of fruiting bodies or mushroom-like growths on the exterior of a standing tree or on the surface of a piece of lumber is by no means a criterion of the extent of the damage which may be wrought inside the material by a wood-destroying fungus. Fructifications or fruiting bodies are less commonly found in softwoods than they are in hardwoods or deciduous trees, especially in the case of heart or butt rots. A butt may be badly rotted and hollow, yet there may be no external sign in the form of conch or fruiting body to indicate the presence of disease in the tree. In the examination of a stand of timber where the presence of decay is suspected, a Pressler borer or similar tool should be used freely near the butts to search for signs of decay. A few blows with a stout pole or stick, with the ear pressed firmly against the trunk, will often indicate the presence of butt rot. The extent of the rot can be further gauged more accurately by use of the boring instrument.

No wood-destroying fungus has the ability to attack all tree species indiscriminately; each confines itself to a particular group of hosts or even to one particular species. It may even confine itself to one particular portion of a tree (roots, butt, trunk, or top), or to the heartwood or sapwood. For example, a fungus such as *Armillaria* which attacks only root systems will not be found at work in the top of a tree.

As a rule, not more than one wood-destroying fungus is to be found at work in the same region of the heartwood of living trees. In the sapwood of living trees, however, and in either heartwood or sapwood, or both, of dead and down material, and in wood products, two or more wood-destroying fungi may be found occupying the same substratum. This fact sometimes complicates the technique of identification of the causal organism of a wood-rot.

As previously explained, the main structure of wood is in the form of cells or fibres, elongated in shape, from ten to thirty times as long as broad, and hollow; they are oval, circular, four-sided, or polygonal in cross-section. When a specimen of standing or manufactured timber becomes infected by a wood-destroying fungus the threads of the fungus work through and along these cells, feeding on the cell contents and on the cell-walls. They also grow along the resin ducts, and by way of the pits

in the cell-walls. They are more frequently found in the medullary rays than in the vertical cells—firstly, because these contain more food supplies for their nourishment; and, secondly, because the walls of medullary-ray cells are thinner than those of the vertical tracheids or fibres. For this reason, medullary rays show the effects of fungous action first, and are more easily penetrable by fungi.

The two main chemical complexes which combine to form the hard wood substance of the cell-wall are cellulose and lignin. Many of the wood-destroying fungi are delignifying fungi, that is to say, they are able by enzymotic action (a digestive process) to abstract the lignin from the



FIG. 17—SKETCH FROM MICROSCOPE (TANGENTIAL SECTION) SHOWING HOW WOOD-DESTROYING FUNGI OPERATE

The holes shown in the cell-walls have been caused by fungous hyphae. Note that the cell-wall in places has been entirely removed.

The structure at the left is a section of a medullary ray.

cell-wall, leaving behind a cellulose complex which is generally whitish, chalk-like and unstable in character. Many of the delignifying fungi produce white mycelial felts in and on decayed wood. Other wood-destroying fungi feed on both the cellulose and the lignin, or on the cellulose alone, forming the body of rots known as brown rots.

All fungi growing in wood, however, are not as drastic in their action as the true wood-destroying fungi. The group known as sap-stain fungi, although they may deeply discolour wood, do not eat away the wood substance to the same extent, but subsist mainly upon the cell contents. Stains are more frequently found in sapwood than in heartwood, probably because of the higher moisture content of sapwood when unseasoned, and its fresher and more abundant supplies of food material. *Blue stain* is by far the most prevalent of the sap-staining fungi, although various shades

of brown, black, yellow, and pink sap-stains are also found (see Appendix A). Pine is much more subject to stain than are Douglas fir and Western hemlock, and Western red cedar is seldom attacked by it. Lodgepole pine (jack pine) is easily blemished by sap-stains, and Western yellow pine is much more subject to sap-stain than white pine. A small amount of sap-stain is allowed in most of the upper grades. This is especially true under the grading rules of the Western Pine Association, under which the Interior pine is marketed. Mechanical strength tests have shown that sap-stains weaken wood only very slightly, and the defect produced by them relates only to appearance. For interior finish, cabinet-work, doors, cupboards, built-in conveniences, tables, and other cheaper furniture which is to be painted, a limited amount of stain cannot be said to affect the utility of the wood. (See plates 48, 49 and 50 on pages 125 and 126.)

In addition to wood-destroying fungi and sap-staining fungi, there is another group of fungi which grow on wet sapwood, forming a fuzzy coat on its surface, called "moulds." As a rule they can be easily brushed off, do not at all affect the strength of the wood, and only to a slight extent its appearance. In most cases the hyphae of the moulds are external, sending out little feeding processes (haustoria) between the superficial cells to absorb nourishment from them. In other cases the hyphae may penetrate the tissues of the wood to some extent, passing in between the cells and often entering them or sending out special feeding processes into them. A green mould, caused by a species of *Penicillium*, is common in coast mills, especially in the autumn. It has been noted in the form of green spots on and throughout the sap of Douglas fir, Western hemlock, and Western white pine, and may develop with great rapidity. It probably occurs also in the sapwood of other species. The coloration caused by this mould is usually obscured in the course of kiln-drying. Moulds are found occasionally in kilns where low temperatures are used over a long period. In kiln-drying hardwoods, where low temperatures are used for a period of thirty to forty days, moulds have been known to develop so luxuriantly as to fill up the spaces between boards.

Certain species of lumber in storage or in seasoning may be discoloured, even disintegrated, by chemical reaction inside such wood, producing the various forms of *brown-stain*. The causes of such chemical reactions are obscurely known (see p. 68). Chemical stains of the sapwood, producing yellow, orange, and other colorations, also occur; usually these are superficial.

Development of Fungi in Wood

As with all living organisms, the growth of wood-inhabiting fungi is governed by four main factors. The absence or removal of one or more of these necessary governing factors results in the prevention of decay, or the preservation of wood. Before one may estimate the efficacy of methods of preservation or prevention of decay it is important, therefore, to understand first what conditions are necessary to produce decay. These are:—

1. Presence of suitable food supplies;
2. A suitable amount of moisture in the wood;
3. A temperature favourable to growth;
4. A supply of air to furnish the necessary oxygen.

Food Supplies.—The mycelium, being actually a living plant, must have nourishment in order to grow. This it finds in the various constituents of the wood substance, in the lignin and cellulose complexes, as well as in

certain sugars, starches, and organic acids present in the cell-walls and their cavities. To break down the woody tissues, which are chemically very complex and stable, certain substances known as "enzymes" or "ferments" are secreted by the growing fungus. The enzymes work upon the wood in a similar manner to saliva in the mouths of animals, reducing the wood to simpler nutritive compounds, and making it assimilable by the fungus.

Artificial preservatives introduced into wood "poison" it, and thus prevent the development of fungi in it. Wood containing appreciable amounts of tannins, oils, resins, and other toxic or semi-toxic substances are thereby afforded a measure of natural preservation. Heartwood contains more of these toxic compounds than sapwood, and a smaller quantity of available carbohydrate food supplies, hence it is less subject to fungous attack, and is more "durable" than sapwood.

Moisture.—A supply of moisture is necessary for the growth of fungi, and as long as wood is kept sufficiently dry, infection cannot take place, nor can fungi which may be already present in the wood continue to develop. Experiments conducted by investigators in Europe and America have shown that a moisture content higher than that at fibre saturation (i.e., about 25 per cent or more of the oven-dry weight of the wood) is required for the best development of fungi in wood.² Between what is generally air-dry weight (about 12 per cent) and the *fibre-saturation point*³ (about 25 per cent) appears to be a range likely to permit fungous growth. Under ordinary conditions, the "critical" moisture content for most fungi in most woods is between 15 and 18 per cent, that is to say, this is the danger point at which fungi may develop. Generally speaking, wood-destroying fungi can attack wood at a lower moisture content than can the sap-staining fungi (including blue-stain). It is probable that a moisture content of at least 18 per cent is required for the development of blue-stain, while a moisture content near fibre-saturation point is required before it can become of practical importance.

Temperature.—Wood-destroying fungi develop best during warm, wet or humid weather, and sap-staining fungi may develop with startling rapidity under these conditions. Temperatures of 70° to 80° Fahrenheit favour the development of most wood fungi, though some of them thrive at considerably higher temperatures, while others thrive at lower temperatures. Growth is generally inhibited at winter temperatures, but cold weather does not necessarily kill them. Heat is more effective in killing fungi than cold, a moist heat being much more effective than a dry heat.⁴ Most wood-inhabiting fungi can be killed and their further development prevented by the application of heat during ordinary kiln-drying schedules.⁵

Climatic conditions have an important bearing upon the life of wood. In out-of-doors situations, warm humid climates encourage the development of rot much more rapidly than cold, dry climates. At high altitudes found in the interior of British Columbia, decay in untreated posts, poles, and other structures is often confined to the wood, at or near the ground-line. In the coastal region decay is not confined to the ground-line, but often spreads many feet above or below it.

²Snell, W. H. The relation of the moisture content of wood to its decay. *Pulp and Paper Mag.*, Vol. 19, p. 531-533.

³Fibre-saturation point is that point in the drying of wood at which the moisture, having been totally driven off from the interior of the cells, commences to evaporate from the cell-walls.

⁴Hoxie, F. J. *Dry-rot in factory timbers* (2nd edition). Boston, 1915.

⁵Hubert, E. E. Effect of kiln-drying, steaming, and air-seasoning on certain fungi in wood. U.S. Dept. of Agriculture, Bul. 1262. Aug., 1924.

Light and Air.—Light is not an extremely important factor, though the majority of fungi seem to develop somewhat better in a diffused or weak light.

A certain amount of air is absolutely necessary for fungous development. Under ordinary conditions the air supply within and surrounding the wood is sufficient. Wood which is submerged in water is said to be immune to fungous deterioration because the air normally present in the cell-cavities has been displaced by water, and fungous development does not take place on account of the exclusion of air.

Stagnant, damp air surrounding a piece of wood is highly conducive to decay. If the wood at first is sound (i.e., free from decay) and dry, it is likely to absorb moisture and act as a host to fungi; while if it is already infected, the moisture supplied will enable the process of decay to continue.

Air currents produced naturally or through ventilation usually cause evaporation of moisture from the wood, and by reducing the moisture content tend to prevent the development of fungi in the wood. They also militate against the development of fungous spores on its surface. As a general rule, ventilation is beneficial; it is possible, however, for well-seasoned timber, continually ventilated with damp air, to absorb sufficient moisture to permit fungi to grow.

Decay Losses in Standing Timber

Many of the commercially valuable stands of this province are composed of "virgin" timber which has been allowed to remain uncut too long and hence is overmature. In this condition it readily falls a prey to wood-destroying fungi and insects. Fungous spores are distributed by air currents throughout such stands and may gain access to the wood through fire-scars, broken branches and tops, bruises, insect borings, etc., or infection may even spread from tree to tree through the soil or through interlacing root-systems.

A United States authority has stated:—"Of the present apparent capital of standing saw-timber in the United States over 300 billion board feet at a low estimate, or more than 14 per cent, must be discounted as cull due to decay."⁶ As forest conditions in the United States are similar to those of Canada, it may be assumed that Canadian losses approximate these figures. As virgin stands are cut, and as second-growth stands increase in volume and extent, decay losses in the forest should be automatically reduced.

Losses in Felled Timber

Timber which has been felled and bucked should be removed from the woods as soon as possible, in order to avoid depreciation as a result of the attacks of insects and wood-destroying fungi. Pinworms and wood-borers are especially active in the spring and summer months. In the coastal region considerable damage, both to heartwood and sapwood, by wood-destroying fungi may occur if logs are left in the woods for many months; sapwood rots are more common than heartwood rots under such conditions. A number of wood-destroying fungi, many of them as yet unidentified, confine their attacks to the sapwood of felled timber and produce the condition known to the lumberman as "deadwood."

⁶Dr. E. P. Meinecke: *Journal of Forestry*; Vol. XXIII, No. 3, March, 1925, p. 267.

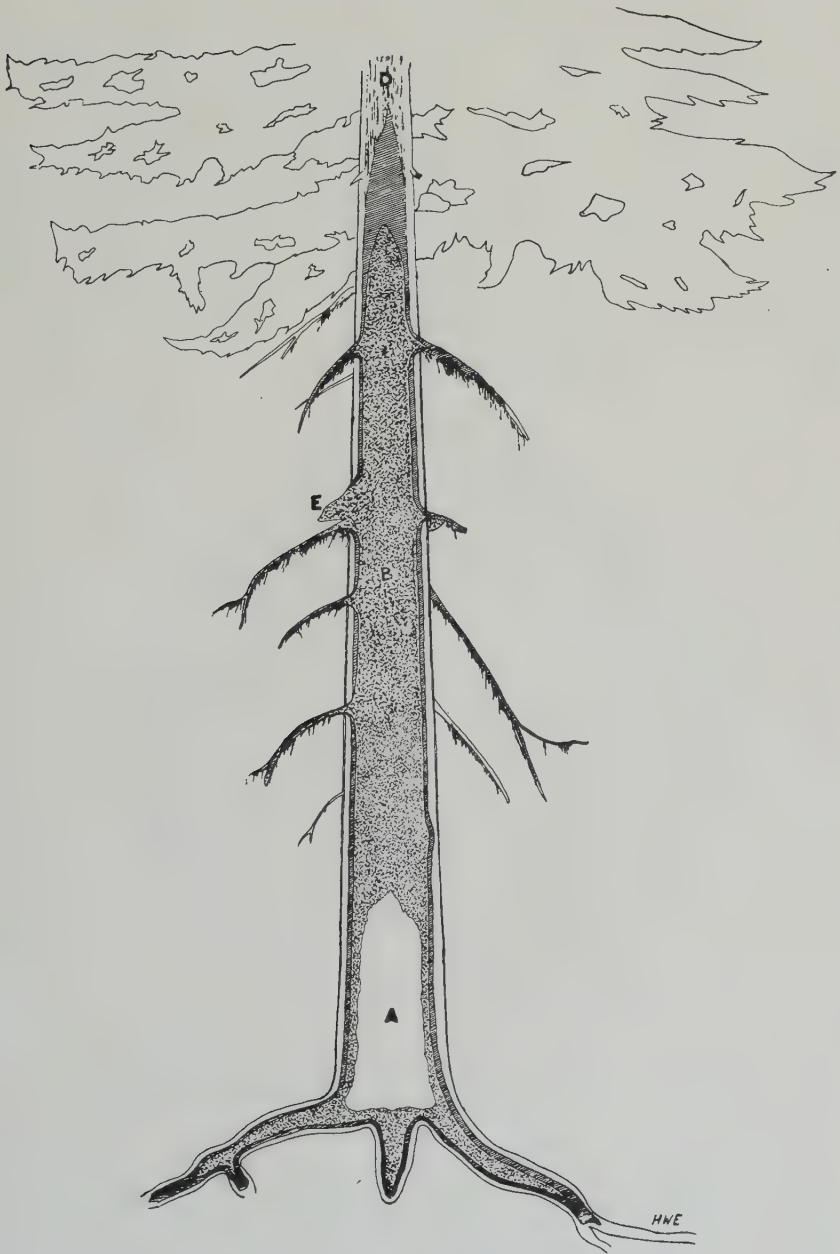


FIG. 18—DIAGRAM SHOWING CONDITION OF A BADLY DECAYED WESTERN CONIFER

- A. Hollow butt
- B. Typical decay
- C. Incipient decay
- D. Hidden stage of incipient decay
- E. Sporophore, or fruiting body

(After Hubert)

In the yellow pine and lodgepole pine regions of the Interior, an exposure of only a few days in the woods may be sufficient to cause the development of blue-stain or brown-stain. If pine logs cannot be removed soon after cutting, they should be decked at various convenient places in the woods with spaces between each log to ensure plentiful air circulation. If the surface layers can be quickly dried out, the chance of blue-stain development will be greatly lessened. If it is inconvenient to deck the logs, or remove them immediately after cutting, then a good plan is to paint the ends of the logs and exposed portions where the bark is no longer in place with a filled, hardened gloss oil or similar preparation. Putting pine logs into the mill-pond is not always a preventive of sap-stain. If the logs float deeply enough immersion is an efficient preventive of sap-stain, but any portion of the sapwood which remains exposed above the surface of the water is in a favourable condition for the development of sap-stain.



FIG. 19—REPRESENTATION OF SAP-STAIN IN A LOG OF WESTERN YELLOW PINE

Note how the zone of stain ceases at the limits of the sapwood

Losses in Seasoning and Storage

The seasoning of lumber consists of the removal of moisture from it until it is in a condition fit for use; this reduction of moisture content has to be accomplished in such a manner that the product is not damaged in any way. Lumber may be degraded during seasoning by checking and warping in their various forms, by chemical stains, by stain and decay, and by the action of insects. Seasoning is accomplished either by air-drying or by kiln-drying.

The latter is the more efficient method of drying lumber from the standpoint of subsequent decay, for it has been found that practically all wood-destroying fungi and sap-stains are killed in the wood by the heat

used in kiln-drying, fungi not being able to stand high temperatures. When the lumber comes from the kiln it is in a "sterilized" condition, and any fungous action which ensues afterwards must come from some exterior source; the moisture content of the wood has been reduced to a low figure (6 to 8 per cent), and it cannot develop fresh mycelium of fungi until this moisture content has been raised. This may occur as a result of hygroscopic absorption from the atmosphere or exposure to the weather.

Kiln-dried lumber should be stored in dry, well-ventilated sheds to prevent degrade from stain and decay. The floors of such sheds should, if possible, be on cement foundations and raised off the ground; otherwise lumber in the sheds may absorb moisture from the ground or even permit the access of insects from the ground which will attack the wood. Occasionally, kiln-dried stock stored in badly constructed sheds has been attacked and partly destroyed by white ants; the home of these insects is in the ground, but when attractive food material like wood is at hand they may emerge and destroy it.

On the Coast, as a rule, only the upper grades are dried in kilns, commons for the most part being seasoned in open storage, though some mills are now turning to the kiln-drying of commons. In the Interior regions kiln-drying of either commons or clears is practised only to a very limited extent.

Stock which is being air-seasoned usually remains in the yard only a few months before it is shipped, and it is doubtful whether there is any appreciable loss in such stock as a result of actual decay. On the other hand, degrade from sap-stain, which may occur in any green stock containing sapwood, may sometimes be serious, because of the rapidity with which it develops. Green sap lumber when freshly piled contains anywhere from 30 to 200 per cent of moisture, which favours the growth of sap-stains, especially in the warm seasons of the year.

On the Coast, kiln-drying has greatly reduced the amount of degrade from sap-stain. Of the Coast species Western white pine is the most susceptible to sap-stain; but the greater portion of the cut of this species, both uppers and commons, is now kiln-dried, thus effectively reducing the development of stain. Spruce, hemlock, and Douglas fir also develop blue or black sap-stains if not dried rapidly enough. Bulk piling of these species for any appreciable time before piling, on the dock awaiting shipment, or while waiting for kiln accommodation, should be avoided. The key to the prevention of sap-stain in air-seasoning lumber is rapid drying, particularly of the surfaces of boards.

In the pine regions of the Interior the amount of degrade from sap-stain is heavy. Staining may be present in logs when removed from the woods, or may develop during manufacture in the course of a few days. The first and the best practical remedy to prevent sap-stain is to dry the stock as quickly as possible, taking precautions to minimize checking.⁷ Western white pine is more subject to check than yellow pine, while yellow pine is more subject to stain; to avoid staining, therefore, yellow pine may be dried more rapidly than white pine. Season checks occur to a much greater extent in the upper parts of a pile than the lower, while of stain the reverse is true. In the pine regions, therefore, where stain is prevalent, drying in the lower parts of a pile should be accelerated by opening them up. The greatest losses from season checks occur during the summer period, when low atmospheric humidity causes rapid drying. The greatest danger of sap-stain development exists in spring and fall.

⁷Fullaway, S. V., and Hubert, E. E. Air Seasoning of Lumber in the Inland Empire. The Timberman March-June, 1925.

Other points which should be attended to with a view to prevention of decay and stain in storage, not only at Interior mills, but also at Coast mills, are the following:—

1. Impediments to air circulation between boards should be removed, and weeds and other vegetation should not be allowed to grow about the piles in the yard.
2. Refuse, broken boards, etc., should not be allowed to accumulate about the yard; such *débris* is simply a breeding ground for wood-inhabiting fungi and insects.
3. Sawdust fills also come within the same category; when these have been made, they should be covered with a thick layer of cinders or sand.
4. The roofs of piles should be water-tight, with adequate overhang at back and front.
5. A clear space at least one foot in depth should extend under the pile.
6. There should be a pitch of at least one foot between front and rear of the average pile.
7. The yard should have adequate drainage.

Losses in Timber in Transit from Stain and Decay

Sea shipments of Douglas fir, Western hemlock, and Sitka spruce occasionally are contaminated by blue-stain and decay *en route*, producing degrade. The Vancouver Forest Products Laboratory is at present studying these losses, and means of prevention.

Fungous losses, principally from stain, take place sometimes in rail shipments, and here the precautions of good ventilation and protection of the shipment from moisture should be followed. Box cars should be used in preference to flat cars. Rubbish, damp sawdust, manure, etc., should be swept out of the cars before use; and roofs should be water-tight.

No comprehensive experiments have been made to determine what effect various antiseptic dips have in limiting the development of sap-stain in lumber which is being sent by rail or by sea. Some mills in the southern United States dip their stock as it comes from the saw, in a tank containing a solution of sodium carbonate (soda ash) or sodium bicarbonate (baking soda). A soda dip applied to green or partially air-dried stock will probably lessen degrade in transit on account of sap-stain.

Kiln-dried finish stock like flooring or finish should be not dipped on account of possible discoloration of the wood. Furthermore, it does not run nearly as great a risk of staining as other classes of stock, because of its low moisture content. In a situation where the moisture content is raised through absorption to a figure (20 to 40 per cent) high enough to permit an appreciable growth of staining fungi, the amount of water imbibed by the wood will often be sufficient to wash away or leach out a previously applied surface film of soda.

Losses in Structural Timber

The aspects of fungous deterioration of wood in the forest, in storage, and in shipment, having been thus outlined, it becomes appropriate to consider the losses from decay which occur when the wood has been used for structural purposes, as in posts and poles, mine timbers, bridge timbers, piling, construction of dwellings and factory buildings, and similar uses.

Annual losses from decay in lumber used for construction purposes assume large proportions. The United States Bureau of Plant Industry, working in co-operation with the United States Forest Products Laboratory, has estimated⁸ that the loss of forest products from decay in 1923 in the United States was \$420,000,000. In lumber volume this represents approximately 4,000,000,000 feet board measure. The possible saving was estimated at \$257,000,000, based on the reduction of the annual demand for wood by better utilization of the material after it is removed from the forest. No figures are available to show the total annual losses from decayed wood in Canada, but it seems reasonable to assume that they are comparable with estimates of losses in the United States. The Forest Products Laboratories of Canada estimated in 1925 that the yearly monetary loss in Canada due to decay of timber used for railway ties, poles, bridges, culverts, etc., was about \$35,000,000. This amount does not include losses from decay in dwellings and similar structures, yet it represents "about 10 per cent of the total value of Canada's primary forest products, more than one-third of the value of the entire production of paper, or nearly three times the value of the total annual outlay for railway ties."⁹

The decay of wood in service was first attributed by the German scientist Liebig to a process known as *eremacausis*, said to cause the disintegration of animal or vegetable matter in contact with air and moisture by slow combustion or molecular motion. This theory was accepted for many years, but was eventually disproved, and the decomposition of wood in contact with air and water is now known to be due almost entirely to the action of wood-destroying fungi, assisted in some cases by the action of soil fungi, soil bacteria, and certain other plant organisms.

Many people in referring to the rotting of wood in service ascribe it to vague processes known as "dry rot" or "wet rot." The term "wet rot" is often used in referring to wood which has been exposed in a wet situation and has decomposed in the presence of moisture, such as wood in posts and poles and mine timbers. The term "dry rot" is widely applied to any decay found operating in wood which is in a comparatively dry condition; but if the moisture content of such wood be ascertained, it will almost invariably be found that it is not dry, but contains an appreciable amount of moisture. Both these terms are unfortunately used, in that they tend to obscure the useful preservative effect which can be attained by keeping wood either very wet or very dry. Water-logged wood cannot rot, and the dryness of wood is, in ordinary circumstances, its best guarantee against decay. The particularly widespread use of the term "dry rot" is to be deprecated in that use of the term tends to obscure the easiest and the most satisfactory method for the prevention of rot in wood.

There are a few fungi, known to wood pathologists as true "dry-rot" fungi, which are able to operate in dry wood. They comprise *Merulius lacrimans*, *Coniophora cerebella*, and some of the *Poria* species (of which *Poria incrassata* apparently is the commonest), but even these fungi need moisture for their growth. They obtain their water supply by conduction from contiguous sources through pipes or strands of mycelium. They are almost universal in distribution, and are particularly harmful because of their ability to destroy dry wood which is in proximity to a moisture supply. The bulk of the decay of structural timbers is due, however, to the work of other wood-destroying fungi than the true "dry-rot" fungi. (For a detailed description of the rots of structural timber, see Chapter V)

⁸A National Program of Forest Research. Society of American Foresters, 1926.

⁹Kynoch, W., in *Canadian Woodworker and Furniture Manufacturer*, March, 1925, p. 53

The decay of wood in service may be due either to the development of decay present in the wood when it is placed in position or to spread of infection from other material. Rots present in the standing tree may continue to develop in the cut lumber if conditions are favourable; and on account of the prevalence of fungi in lumber yards there is always a strong possibility that these may be introduced into buildings through lumber and other supplies. The danger of decay development is greatly reduced when the wood is dry; therefore, to reduce decay of wood in service, the main precaution to be observed is to maintain it in a dry condition. Usually this can most effectively be done by ventilation. In cellars and mines it may not always be possible to secure sufficient ventilation to keep the wood dry, but in buildings and other structures above ground it should be a primary structural consideration. The use of partially seasoned or green wood (especially sapwood) is always a predisposing cause of the development of rot.

An important point to remember in connection with the decay of structural timber is that many rot organisms are to be found in the soil and that moist conditions enable them to grow abundantly. Regardless of ventilation, any timber which forms direct contact with the ground will permit rot to pass upward from the ground. Such a condition may in addition permit the attacks of white ants and other wood-destroying insects whose normal habitat is in the ground. For these reasons wooden posts for the support of a building should never be placed directly on the ground, but should rest upon concrete footings; no stringers or sills should be allowed to remain in contact with the soil; and there should always be ample ventilation in basements and beneath the ground floor. Wood forms about concrete work should be removed as soon as the concrete has set; and all woody debris which may have accumulated beneath the building during construction should be removed. When a building is used for manufacturing purposes which are of such a nature that the air within is saturated with moisture all or most of the time, condensation may result through cooling by the outside air at the roof and upon the outside walls, producing decay. Leakage from roofs, from plumbing, around windows, doors, seepage through stucco, sweating water-pipes, are all predisposing causes of wood-rot in buildings.

Wherever a serious attack of rot has been located in the foundation timbers of a house or in similar positions the infected material should be cut out as soon as possible and burned. Not only should the obviously rotten portions be removed, but timber for two or three feet beyond the limits of the detectable decay should also be cut out. Woodwork which adjoins the infected portions should also be removed. If the joists of a floor are found to be infected, it will probably be found that the heaviest infection lies between the walls and the ends of the beams supporting the joists, and where the ends of the joists touch the wall. Such wood-work should be removed, therefore, as will enable those portions to be thoroughly sterilized. This may be done by applying several successive dressings of some antiseptic like dilute formalin. The surfaces of masonry and brick work exposed by removal of the wood should be heavily washed with the antiseptic or sterilized by the application of heat from a plumber's blow-lamp.

Treatment with antiseptics cannot compare with ventilation as a preventive of decay in buildings and dwellings. Good ventilation provides more lasting protection, is less expensive, and does not entail the expense or inconvenience of handling of many artificial wood-preservatives. For outdoor structures, treatment with creosote gives a certain measure of security, but absolute protection can be secured only by thoroughly impregnating the timber with the antiseptic; this naturally adds consider-

ably to the cost of such structures. Surface coatings greatly decrease the chances of infection in sound wood, but if the lumber is moist inside and contains wood-destroying fungi a surface coating is of little value.

Antiseptics and Preservatives

Reference has already been made to the lessening of decay losses by removal of sources of infection, and by adjusting physical conditions to prevent development of the fungus. The remaining method to consider is the use of chemical antiseptics and preservatives. Apart from the actual design of exposed wood structures, the application of preservatives to wood is the most effective method of preventing decay.

There is a number of preservatives which have proved effective in preventing decay, moulds, and stains; when they are applied to wood the food supply of the fungus is poisoned, so that its growth in the treated portions cannot be sustained. For structures exposed to the weather, or below the ground-line, in bridges, wharves, piling, railway ties, posts and poles, *creosote* has been the most widely used preservative up to the present time. Not only does it prevent fungous growth, but it resists the attacks of teredos and other marine organisms and of insects. Its greatest value lies in the fact that it cannot be leached out by water. The wood must be impregnated under pressure if it is desired to secure a deep penetration. Creosote has a pungent odour, and it increases the inflammability of timber immediately following treatment. After six months' exposure to the weather, however, the volatile part of the creosote has left the wood, and it is then very little, if any, more inflammable than it was before treatment.

So-called crude oils¹⁰ are sometimes mixed with creosote, when their main purpose is to act as a "carrier" for the creosote and ensure deeper penetration. Crude oils used alone, especially those with an asphaltic base, may exercise a water-proofing effect and thus keep the wood dry enough to inhibit fungous growth, but their actual toxic value is very small. Used alone they do not penetrate the wood as easily as creosote. Coal tar is also used as a dilutant and a carrier for creosote in wood-preserving processes; in addition, it has a certain toxic value in itself.

Other antiseptics are in use, but most of them are lowered in efficiency by the fact that they soon leach out when exposed to the weather. They include mercuric chloride, sodium chloride, sodium fluoride, copper sulphate, zinc chloride, and sodium carbonate and bicarbonate, which are all soluble in water. Mercuric chloride has a more toxic effect than the other soluble preservatives mentioned, but on account of its very poisonous nature it is dangerous to handle, while copper sulphate sometimes imparts a blue tinge to the lumber and has a corrosive effect on iron and steel.

Just before the war a number of British Columbia mills tried the use of sodium carbonate and bicarbonate as a preventive of sap-stain, but these two chemicals were not found in practice to be entirely satisfactory. Their toxicity was found to be limited, and they discoloured the lumber, giving rise to a yellowish colour. They were, furthermore, easily leached from the surface of the wood by rain, and were said to attract moisture hygroscopically. Their use in this province of recent years has been largely discontinued.

The best remedy for the sap-stain problem in the mill-yard seems to lie in rapid handling of the lumber and improvement in yard sanitation. The lumber should be piled as quickly as possible after it has left the saw, crossed with cedar or crossers of other species than the lumber piled, and all débris and rotten lumber should be removed from the yard and burned.

¹⁰The crude oils of commerce, which may be of either asphaltic or petroleum base, are seldom "crude" or in their natural condition, the gasoline, lubricating oils, and other fractions having been previously distilled off.

CHAPTER IV

RECOGNITION OF DEFECTS CAUSED BY STAIN AND DECAY

Detection of Wood Decay

At first thought it may appear to be an easy task to tell from its appearance whether wood is "rotten" or not, but the progress of decay in wood is cumulative in effect, and the earlier stages of decay may easily elude observation during a visual inspection. In examining wood for the presence of decay the colour of the affected parts is an important indicator, also the manner in which the wood substance reacts to the fungus, but in many cases the action of the invading fungus may be so little advanced or so obscured that laboratory examination may be necessary to detect its presence.

Identification of a particular fungus which is causing decay, either in advanced or early stages, may be a still more difficult task, because many wood-destroying fungi produce a similar appearance in infected stock. If the decayed specimen has attached to it a *sporophore* or fruiting body of the causal fungus, identification may be readily based upon the fruiting body, for nearly every species of fungus has a fruiting body peculiar to itself. Fruiting bodies do not grow upon manufactured lumber as readily as they do upon trees or logs.

In its earliest stages the presence of decay is often not discernible, and at this time the strength of the wood, the continuity of the grain, and consequently the utility of the wood, cannot be considered to be impaired. As decomposition progresses, the fungus produces more marked colour changes in the wood, and it eventually becomes whitish through delignifying action, bleaching, or similar causes, or it becomes yellow, red, or brown, due to cellulose-dissolving action, or other causes imperfectly understood at present. Confusion may occur in estimating the significance of the various colorations which may occur in wood, unless care is exercised. Colorations natural to the wood, as well as those caused by bird, insect, or other wounds may sometimes be wrongly attributed to decay. Colour changes produced by decay vary not only with each fungus, but even according to the species affected. Some rots produce marked colour changes in their early stages, while others show no perceptible colour variation from the normal, even in quite an advanced stage of decay. The task of finding out whether or not decay has entered into an individual piece of lumber thus becomes greatly complicated. Usually in the advanced stages of decay the wood structure is obviously seen to be breaking down. The strength of the wood lessens appreciably, and changes in texture and continuity of the grain occur, as well as frequent marked changes in colour. The early stages of decay are generally known as *incipient*, while the later stages of decay are known as *typical*, but no hard and fast lines can be drawn between the two.

It is important to remember, in cutting out portions of badly decayed wood, that incipient decay invariably surrounds the typical decay, even though there may be little or no discoloration to indicate this. In cutting

out infected pieces a margin of safety of at least two feet in a longitudinal direction beyond the last visible trace of incipient decay should be made, in order to be sure of removing all infected wood.

Classification of Wood Rots

Some fungi confine their activities to certain softwoods, while others are found only in hardwoods. Some work in living trees, others work only in dead or down timber. Some are found most frequently in sapwood, others only in heartwood. Others find the spring-wood in each annual ring more easily attacked and demolished than the summer-wood, probably on account of the thinner walls of the spring-wood, and the supply of air available in the larger cell-cavities of the spring-wood. In such cases a type of decay often results in which the annual rings split apart in a cylindrical fashion, producing what is known as a "laminated rot," "ring scale," or "ring rot." Some fungi produce brown rots, others white rots, and others pocket rots. As the appearance produced in wood by the various important wood fungi and their habits are known, it is often possible by comparison with these known standards to definitely identify the actual causal organism of a wood rot, even in the absence of sporophores. There are certain fungi which produce similar effects in infected wood, particularly in the incipient stage, and definite identification of the causal organism by visual inspection of the wood becomes impossible in such cases.

For convenience in classification the rots of heartwood may be subdivided into top rots, trunk rots, butt rots, and root rots, because many fungi show a distinct preference for one of these portions of the tree. Butt rots like *Polyporus Schweinitzii* frequently extend deeply into the roots also. The name "root rot" is generally applied to such rots as *Armillaria mellea* and *Fomes annosus*, which attack the root sapwood. *Armillaria* seldom does damage to the trunk or butt, but is confined to the roots. Generally speaking, sapwood rots are much more frequently found in dead or down timber than in the living tree, and their action is seldom localized in certain portions of the trunk.

Another method of classification¹ is that based upon the typical reaction produced in the wood by the fungi, namely, division into white or brown rots. White rots are caused mainly by delignifying fungi, but sometimes by a bleaching action. They may be subdivided into white pocket rots, white ring rots, white mottled rots, and white spongy rots. The white pockets or blotches caused by this group of rots are responsible for the "white specks" familiar to the lumberman. The second group, the brown rots, caused principally by cellulose-dissolving fungi (but not confined to these) show reddish, brownish, or yellowish discolorations in their typical stages. They comprise the brown pocket rots, brown ring rots, brown stringy rots, brown cubical rots, brown spongy rots, and brown mottled rots.

This method of classification into brown rots and white rots is the best basis of classification when close laboratory examination is not possible. Because of the sometimes faint definition of incipient decay, and the fact that the incipient stages of many white and brown rots are similar in appearance, identification of a causal fungus in the incipient stage is usually difficult. White rots sometimes produce a noticeable effect in their incipient stages, but brown rots are often obscured by the natural colour of the wood until quite an advanced stage of decay has been reached. For this reason brown rots probably cause greater economic loss. Coupled

¹ Mentioned by Dr. E. E. Hubert in *Diagnosis of Decay in Wood*. Jour. Ag. Res., Vol. XXIX, No. 11 (Dec., 1924).

with the colour of the wood in the typical stages, other features which help materially in classifying causal organisms are changes in texture and continuity of the grain produced by the rot, its character (whether or not it is laminated), its location (whether in heartwood or sapwood, in the standing tree or in cut lumber), the portion of the tree in which the rot is found, and the species of the wood specimen in question.

Incipient Decay

By far the commonest fungus encountered in commercial timber and lumber in British Columbia is *Trametes Pini*, a white pocket rot (in its typical stage). It is responsible for most of the "red heart" and "firm red heart" common in Douglas fir. The incipient discoloration produced by this fungus is not always reddish, but may be pinkish, brownish, or purplish. Other white pocket rots which produce these uniform colorations are *Polyporus anceps* and *Fomes annosus*; the brown rots *Fomes officinalis*, *Fomes roseus*, *Polyporus sulphureus*, *Polyporus Schweinitzii*, *Fomes pinicola*, and some others, produce in their early stages pinkish to brownish discolorations which are similar and which complicate identification. None of this group is nearly as wide-spread as *Trametes Pini*. The later stages of decay produced by this fungus exhibit a series of narrow pockets or pipes scattered through the wood, varying from one-quarter of an inch to one inch in length, and about one-sixteenth of an inch wide, with their length parallel to the grain of the wood. The pockets are filled partially or wholly with a white celluline substance.

Another fungus which has been found to be prevalent in Douglas fir is *Fomes officinalis* (*F. Laricis*). Two forms of coloration in Douglas fir, caused by rot, have been frequently noticed. The commonest form is a reddish-purple, uniform stain which is found in the shape of irregular pipes. This form of stain is very similar in appearance to that produced by *Trametes Pini* in Douglas fir, and cannot be differentiated from it in the early stage of decay. *Fomes officinalis* may also produce in Douglas fir a uniform bluish-purple or violet discoloration, which sometimes makes the wood seem to have been stained uniformly by a violet dye. Both these colorations—unfortunately for purposes of locating the incipient decay—fade out on the surface in a day or so when exposed to the light, leaving only a dull brown colour in the wood, which can hardly be distinguished from normal sound wood. The colour produced in the incipient stage by *Trametes Pini* also fades out when exposed to the light.

In Western yellow pine the early stages of *Polyporus anceps* (*Polyporus Ellisianus*) show reddish or reddish-brown areas² radiating from typical rot areas as seen in the transverse section.

Echinodontium tinctorium is prevalent in true fir (balsam), spruce, and Western hemlock. With this fungus the incipient discolorations extend some distance ahead of the typical stage.² The discoloured areas fade out as the wood dries, and for some distance beyond this limit the action of the fungus continues, so that sometimes apparently sound boards which have been cut from parts infected by this fungus are found to have a brashy, crumbly texture which renders the wood unfit for commercial use.

Fomes pinicola is another brown rot whose incipient stages show very little visible trace. This fungus is perhaps the worst enemy of felled timber in British Columbia, yet its presence may not be apparent until the rot is quite well advanced.

²Hubert, E. E. Diagnosis of Decay in Wood. Jour. Agr. Res., Vol. XXIX, No. 11 (Dec. 1, 1924), p. 528.

It is sometimes contended that a purplish or pinkish discoloration or a section of "red heart" in a piece of lumber does not indicate the presence of *Trametes Pini* or any other rot. Opinions are frequently expressed that discoloured portions of a board are due to "mineral stain," or to "water-soak," or to "just the natural colour of the wood." It is a fact that certain British Columbia timbers—notably Western red cedar and Douglas fir—may show marked variation in the colour of the heartwood; but where the coloration is natural it is usually uniformly distributed through certain annual rings, not through portions of them, nor in irregularly defined patches. Where such irregular pipes of purple, pink, or reddish wood are found, they should be looked upon with suspicion as possible indications of infection by wood-destroying fungi.

Lumber containing detectable decay of any kind should be excluded from the upper structural grades. The identification of incipient decay by visual inspection can be done with reasonable accuracy only by men well acquainted with lumber and the real significance of the various defects and discolorations commonly appearing in lumber. Absence of actual disintegration of the wood substance in a piece of lumber is by no means a guarantee that it is sound. The task is complicated by the fact that many of the purple and red stains which accompany, and are an indication of, decay fade out at the surface of the wood after a day or two of exposure to daylight, leaving behind only a brownish discoloration which cannot be readily differentiated from normal wood. Because the colorations may be concealed in the interior of a piece, or because they may have faded out, it is not always possible to cull purple and red portions from timbers graded upon a strength basis, but it should be continually borne in mind that such discoloured, incipiently decayed wood may be as much as 20 per cent, or even more, below strength when placed in position, although no actual disintegration of the wood may be visible, and that timbers carrying such incipiently decayed portions are likely to rot further when placed in position and exposed to the weather. In bridge timbers, mine timbers, cross-arms, and similar woodwork, where collapse of the wood through decay would be dangerous to life and limb, the use of such discoloured wood should be avoided.

A striking illustration of the extent to which a piece of wood may be decomposed when it merely shows a reddish or a purple discoloration is sometimes seen in pieces of timber which have just come through the dry kiln. When it went into the kiln a piece may have seemed unblemished, except for the discoloration, but when removed from the kiln the discoloured portions of the wood may be noticed to have crumbled away, even to a powder. Certain chemicals produced in the rot process have undergone reaction under the influence of heat, and partly decomposed the wood. Such pieces of wood are generally called "kiln-burned," but the kiln is not to blame for the occurrence. The original cause is the fungus which entered the wood and commenced the process of decay.

Besides the colour method, which when used without other criteria is unreliable in detecting the incipient stages of the brown rots, the presence of fungi can be determined sometimes by the condition of the wood fibres. Hardness, elasticity, and brashness of the wood are all characters of significance in detecting the presence of fungi in wood. The hardness of a doubtful piece may be tested by jabbing a knife blade or a dull point of some kind into the wood. The manner in which the wood takes the point

is indicative of the extent to which it may be decayed. A common test employed by inspectors of aeroplane material consists of prying out some of the fibres with a knife point or other sharp tool to test the elasticity. If the wood is sound the fibres are dislodged with difficulty, and cohere with, and present a splintery appearance in, the wood. If unsound they pull out easily and break off in a brittle fashion. Wood which has brittle fibres is called *brash*. Such a test may also be used to detect the presence of spiral grain.

In certain species, especially in Western hemlock, a dark, sodden area in the heartwood may be found which has the appearance of being soaked by water. This is sometimes a sign of fungous infection. When it occurs in hemlock it is likely to represent the incipient stage of the fungus *Ganoderma oregonense*. When the wood dries out, the water-soaked areas cannot be defined.

The expression "*mineral stain*" is often used to denote colorations in lumber for which the grader or inspector is unable to account. The bulk of so-called "*mineral stains*" should be rightly called incipient decay, though some of them are due to resin streaks, and others to wound discolorations. In using the term, it is assumed that certain chemicals have risen up the tree with the sap, thus colouring the wood. This is possible where a tree has been growing in ground where there are copper or other mineral deposits, but it is not likely to occur very often.

Zone lines are strongly marked, narrow, irregular, and continuous lines which occasionally surround areas of decay in wood. They may be of various uniform colours—orange, black, or, in fact, almost any colour in the solar spectrum. Their origin is imperfectly understood; they may denote the limit to which decay has progressed, or they may indicate the boundary between regions of attack of two fungi. They are said to appear in connection with the white rots, and rarely with the brown rots. They are useful in assisting to locate the presence of incipient decay, but they have no systematic value in identifying individual causal fungi.

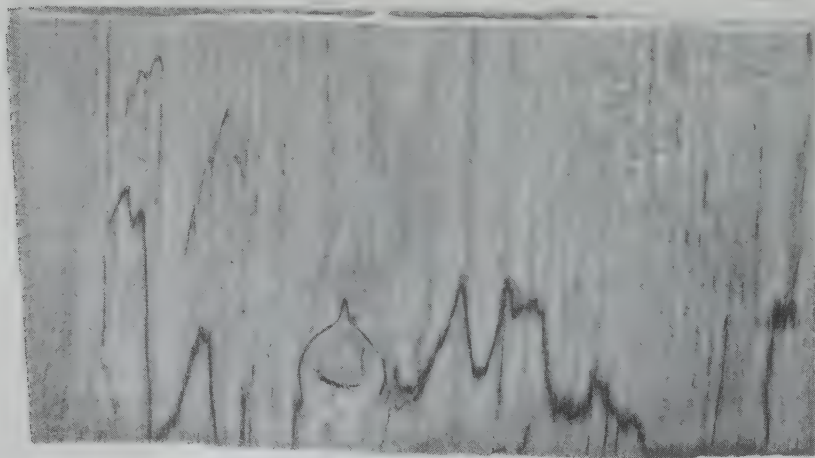


PLATE 31—Zone lines (causal fungus, *Trametes Pini*) in Spruce

Discolorations Other Than Those Caused by Incipient Decay

Irregularly defined patches of purplish, reddish, or brownish wood surrounded by wood of normal colour should be looked upon with suspicion as possible beginnings of decay. Not all colorations which vary from the normal, however, should be ascribed to wood-destroying fungi, and knowledge of the significance of such colorations is necessary if the grader or inspector desires to be able to distinguish colorations which are a mark of decay from those which are not.

There are, firstly, the various resin (pitch) defects outlined in Chapter I. There are also certain normal color variations in the different species, with which the practised eye is familiar; discolorations due to chemical changes in the cell contents; others due to various wounds sustained by the tree, whether by fire, wind, lightning, insects, birds, or the hand of man; lastly, the sap-stains, due not to chemical action, but to the action of certain fungi which sometimes develop rapidly in the wood, but have little or no effect on its strength, and are therefore not classed as wood-destroying fungi.

Normal Colour Variations

In Western red cedar the colour of the wood varies from straw colour to purple or deep brown, and occasionally pipes or zones of yellow or even white wood may be found intermingled with the heartwood. Often these are portions of the sapwood which have not been changed into heartwood (see p. 9); such wood is known as *internal sapwood*. The same occurrence has been noted in Douglas fir and Western larch.³

In Western hemlock and amabilis fir the normally straw-coloured wood frequently has a streaky, purplish appearance, which is natural to both woods and has no significance whatever in relation to strength or decay.

The heartwood of Western white pine often assumes a pinkish or even wine-red colour in air-drying. This colour is not confined to the surface layer but is uniform throughout the wood. The colour has no relation to decay, and even improves the appearance of the wood.

In Sitka spruce the normal heartwood has a slight reddish tinge. Some trees have a decided pink-coloured heartwood, which is quite as strong as normal heartwood.

In Douglas fir the slow-grown "yellow fir" differs from the faster-grown "red fir" (first and second growth). Occasionally these two varieties of wood will appear in the same tree. If the coloration extends from end to end of the log, extends uniformly through certain annual rings, or uniformly throughout the heartwood, it is probably not of fungous origin. If the colorations appear in pipes or patches, and are located in certain portions of the piece only, then it is likely to denote the presence of red rot (*Trametes Pini*), or some similar fungus.

Colour Changes of Chemical Origin

The observation of coloration with a view to detection of incipient decay should be made when the wood is fairly green, because in seasoning (either by air-drying or kiln-drying) colour changes occur which may completely change the aspect of the wood, and make it imperative that accurate examination of decay and other blemishes should be made on the freshly cut surface.

³Koehler, A. Guide-book for the identification of woods used for ties and timbers. U.S. Forest Service, Forest Products Laboratory.

All woods gradually change their natural colours on exposure to light and air, the changes usually being most noticeable in lighter-coloured woods. First they become yellow, then grey, and often finally assume a dark-brown "weathered" colour. These colour changes occur only on the surface of the wood, and the stronger the light to which the wood has been exposed and the longer the exposure to the elements, the darker is the shade of brown or grey it eventually assumes. The change in colour is due to chemical reaction in the surface layers, and has no weakening effect.

Quite vivid, rapidly developing colour-changes may occur upon sapwood or in the outer heartwood, in the presence of light, due to a chemical process which takes place in the contents of the wood-cells (see Plate 32). The exact chemical reaction or reactions causing these discolorations are unknown, but they are generally accepted as being due to oxidation of certain constituents in the cell contents. The colours produced vary greatly, but the commonest seem to be lemon or orange, and various shades of yellow and brown. Hot weather, with high atmospheric humidities, is favourable for this action, while cool, dry weather retards it or prevents it entirely. The stain is confined to the immediate surface layers of the wood and has no weakening effect upon it. A suggested method for its prevention is plunging the boards into boiling water for a few moments as they come from the saw,⁴ but it will not often be thought worth while to do this with softwoods. Hardwoods are much more subject to chemical stain than softwoods. (See plate 32, page 123.)

Brown-stain

Of the chemical stains, the most troublesome and the most frequently found is brown-stain. It is the only chemical stain which seriously affects wood. Other chemical stains are generally confined to the immediate surface layers of the wood, but brown-stains may penetrate below the surface layers of sapwood and heartwood alike and even affect the whole piece. Normally, brown-stain affects only the surface of boards, and such a blemish is easily planed off in the machines. In some cases it lies hidden beneath the surface and is exposed only when the piece is being machined or finished. Western white pine (*Pinus monticola*) and Western yellow pine (*Pinus ponderosa*) are subject to brown-stain; it has also been found in Douglas fir and Western hemlock.

Chemical brown-stains are usually divided into two classes, viz., "yard brown-stain" and "kiln brown-stain." The chief advantage in the use of both these terms lies in the fact that they are self-explanatory in regard to the place of origin of the defect, that is to say, whether it occurs in the yard or in the kiln. Both of these defects may be brownish or yellowish, or of orange colour, and differ little in their general appearance. They are quite likely to be of similar chemical origin.

The chemical processes which cause brown-stain in kiln and yard are so complex as to have eluded so far the efforts of chemists to understand them. Various theories as to its cause have been advanced by competent observers, such as oxidation of the cell contents or caramelization of the sap. The most generally accepted theory at the present time is that brown-stain is due to oxidation of the cell contents. The wood of pine and other softwood species—especially the sapwood—contains certain organic compounds and certain soluble ferments which may cause oxidation of such compounds, imparting coloration to the wood. Completion of the oxida-

⁴Bailey, I. W. Oxidising enzymes and their relation to "sap-stain" in lumber. Bot. Gaz., Vol. 50; p. 142-147. 1910.

tion process may not take place until the boards have been exposed to the action of light, when the colour of the defect is deepened and becomes more apparent. It has been claimed by several investigators that the age and condition of the timber have an effect in determining the development of chemical brown-stain and that it appears to be worse in older timber. It is likely that, with age, the wood structure becomes modified so as to prevent the even circulation of moisture from the wood in kiln-drying or air-seasoning, with the result that oxidizable elements collect at certain points in the piece.

Recent experiments in the United States have shown that brown-stain does not take place in the kiln until the stock is below the fibre-saturation point, and that temperatures up to 180° Fahrenheit may be used up to the fibre-saturation point with little or no effect upon the eventual development of brown-stain. It has been recommended as a result of these experiments that *Pondosa* pine (Western yellow pine) should be kiln-dried at an initial temperature of 180° Fahrenheit and kept constant to about fibre-saturation point, when it should be dropped to 130°, and this temperature kept constant during the remainder of the drying period. Under these conditions adequate circulation of air currents in the kiln is necessary.

Incipiently decayed lumber, in the yard or in the kiln, may undergo marked changes under the influence of temperature and moisture. As incipient decay is sometimes hard to detect, boards containing it may sometimes be placed unnoticed in the kiln charge. After the drying period is over, such boards may be found to be totally or partially brittle, brashy and unfit for use, and a stout blow may shatter such a board into pieces. Again, discoloured patches in a board, denoting the presence of incipient decay, may spread considerably in extent while in the kiln, and in some cases the discoloured portion, seemingly firm and sound when inserted in the charge, is found on withdrawal to be dark-brown, cheesy, or crumbled. Although the nature of these reactions in incipiently decayed wood is only obscurely understood, it is apparent that they are chemical in nature, and that the chemicals formed in the wood as a result of the action of wood-destroying fungi undergo rapid reactions under the influence of the kiln temperature and cause rapid decomposition of the wood substance.

Similar extension of decay areas through chemical reaction in the presence of heat may take place in boards in the storage or seasoning pile, to which the term "pile-burn" is usually applied. Boards at the bottom of old storage piles which have begun to disintegrate owing to the action of wood-destroying fungi, consequently, have a crumbly, brownish exterior, and are also frequently called "pile-burned."

The term "*kiln-burn*" is often vaguely applied to any brown discoloration or decomposition which may occur in a kiln, but it is distinctly out of place, because it implies a burning or browning through the use of excessive heat. Actual scorching or charring of wood in a kiln must be of very infrequent occurrence, since the temperatures used in steam kilns are seldom high enough to cause actual burning. The term "pile-burn" is also unfortunately used, because it implies scorching or charring by the rays of the sun, which is unlikely in northern latitudes.

To recapitulate, therefore, two forms of chemical brown-stain may occur in yard or in kiln. The first has a discolouring effect upon wood, and has no influence upon its strength; the second not only discolours wood, but may have a drastic effect upon the cohesion and usefulness of incipiently decayed lumber.

Brown-stains of chemical origin may be confused with other brown-stains of lumber, unless care is exercised. Brown-stains in lumber may be classified as follows:—

Brown-stains Caused by Fungi—

1. Decay stages of certain wood-rotting fungi;
2. Brown sap-stain: this is caused by a fungus resembling blue-stain in its action on wood, and in the pines may be found working side by side with blue-stain. Its colour may be a deep chocolate-brown, but it does not affect the strength of the wood. It rarely appears in heartwood, generally only in the sapwood. Its colour is a much richer brown than that caused by brown-stains of chemical origin, and is usually uniform, whereas the colour of chemical brown-stain is generally variable and blotchy. Among softwoods this fungus confines itself largely to the pines.

Stains Due to Burning—

1. *Kiln-burn*—an actual scorching or burning of the wood through heat. Of infrequent occurrence. This term is often erroneously applied to chemical stains produced in the kiln.
2. *Machine-burn*—this type of discoloration occurs in finished stock. The scorched areas develop when the progress of the piece through machine or saw is retarded, and heat is generated by friction.

Water Stains—

1. Yellow-brown to black stains, caused by dripping of water upon the surfaces of boards, either in the kiln or in seasoning and storage.
2. A dark, henna-brown surface stain which may appear on Western hemlock boards while in the kiln, due to particles of tannin-laden vapour from the wood condensing and falling upon it. Such stains usually plane off readily.

Chemical Brown-stains—

1. *Yard brown-stain.*
2. *Kiln brown-stain.*
3. Brown-stains produced in kiln or yard due to chemical reaction in partly decayed wood.

Discolorations Due to Wounding

As applied to trees, a “wound” means not only an obvious rupture of the woody tissue or a major injury of some kind, but also less apparent injuries to the delicate cambium layer which lies between the sapwood and the bark. When the cambial tissue at any point is injured or killed, growth or addition of wood-cells immediately ceases at that point, and a healing or callousing process sets in which aims at covering up the wound. When the wound has healed over, growth continues as before, but where it has lagged on account of injury, a dip is left in the grain which may persist throughout the future life of the tree. Such an irregularity in the grain of lumber, therefore, often indicates the occurrence of a wound of some kind (see Chapter I, section on *Grain*, page 17).

Wounds may arise from a variety of causes, among which are fire, lightning, birds, insects, or mechanical injuries of various kinds. About each wound area local discolorations are frequently seen—more frequently

in hardwoods than in softwoods. The terms "mineral stain" and "water soak" are often applied to such discolorations, but they are distinctly inapplicable.

Lightning Injury.—When lightning strikes a tree it may produce such drastic results as rending or splitting apart the trunk, shattering the base, so that the otherwise uninjured tree collapses, stripping all the bark from the tree, or the ploughing of characteristic grooves down the bark and wood of the trunk. A stroke of lightning may also shatter the top, producing what the woodsman knows as a "spike top" or a "stag head."



PLATE 33—Lightning injury in Douglas Fir

A less destructive but common type of lightning injury occurs when only the delicate cambium (which is very sensitive to electric discharges) is affected. Sometimes the whole of the cambium layer about the tree may be killed; sometimes only certain small portions of it may be affected. In softwoods cambial injury is frequently associated with the formation of chains or groups of resin cells or traumatic resin ducts, generally in the form of a peripheral chain or band, which is confined to one annual ring extending about the trunk for a varying distance. When a band of resin cells appears in a board it forms a possible line of cleavage and therefore a source of weakness, especially if there is any tendency to warping or checking. On account of the frequent narrowness of the zone of resin cells, detection of these lightning rings in rough lumber is extremely difficult, unless wound discoloration accompany the injury. When they are small, these wounds resemble sapsucker wounds, but they may penetrate and discolour the wood for as great a distance as several inches in the direction of the pith, and as much as two feet vertically beyond the limits of the actual wound.

In light-coloured woods such as amabilis fir and Sitka spruce, lightning rings are detected more readily than in darker woods such as Western red cedar and Douglas fir.

Bird Injuries.—Bird injuries take the form of small punctures. When made by sapsuckers (members of the woodpecker family) their purpose is to allow the birds to eat the cambium and extract sap from the sapwood.

Woodpeckers and other birds also bore holes in the bark for the purpose of finding the grubs of beetles. Bird injuries occur with varying frequency, so that certain trees may be covered with holes, while others may contain only one or two. In a board a bird injury is apparent as a small T-shaped blemish, with the leg of the "T" in the form of a small radial check. About the wound is a brownish or purplish discoloration, usually caused by the infiltration of resin about the wound point. *Bird pecks* (the name usually applied to such injuries) affect the appearance of a board, but not its strength to any appreciable extent. The grain of the wood about these small injuries is liable to be distorted somewhat, so that in sheets of veneer small pieces of wood including bird-peck injuries may fall out, and in finished lumber the surface may be roughened up at these points. Practically all tree species are liable to this form of defect, and much of the curly grain found in cottonwood, poplar, maple, and other woods may be partly attributed to distortion of the grain caused by bird-pecks.

Bear Scratches.—This type of blemish has been noticed only in Sitka spruce, but is quite common in that species. On the longitudinal or flat-grain surface it is seen as a series of vertical, undulating "scratches." The wood inside the "scratch" is soft and there is a slight disturbance of the grain about it. The depression is continuous from ring to ring, presenting the appearance shown in plate 13 (page 20). The slight reduction in strength caused by local distortion of the grain about bear scratches may be said to be negligible. They are not caused by bears, and are probably due to the action of a fungus growing in the cambium layer (see page 21).

Bird's-eye.—Bird's-eye may appear on occasion in almost any western species. It has been noticed particularly in Western maple, lodgepole pine, Western yellow pine, Western red cedar, Douglas fir, cottonwood, amabilis fir, and Sitka spruce. This defect is said to be due to the action of adventive buds, mistletoes, and various types of wounds, but probably most frequently to the action of a parasitic fungus in the cambium layer (see page 21). A peculiarly figured blemish in Western hemlock is also probably due to this latter cause. (For bird's-eye in Douglas fir, see plate 11, page 119.)

Discolorations Caused by Sap-stain

Among Western woods the pines are particularly subject to sap-stain; Western yellow pine is more affected than Western white pine, and lodgepole pine is also very subject to this stain. Spruce is somewhat less susceptible to sap-stain than the pines; Douglas fir occupies an intermediate position between these and other softwoods less affected, such as true fir and Western red cedar.

Blue-stain is the commonest form of sap-stain; it may turn almost black in its advanced stage. Brown sap-stain is very common in the pines; its colour is generally dark chocolate-brown. Brown sap-stain may be distinguished from yard brown-stain and kiln brown-stain (chemical stains) by remembering that the latter is a lighter brown or yellow colour and appears on the tangential surface of the wood in irregular blotchy patches. Brown sap-stain (a fungal infection) is generally confined to the sapwood, where it appears in layers usually conforming to the outline of the annual rings. Both blue and brown sap-stains may occasionally appear in the heartwood as well as in the sapwood.

Other sap-stains may be pink, black, crimson, violet, grey, and lilac colour, caused by various species of fungi. A reddish stain sometimes occurs in Sitka spruce in storage or in transit by rail or sea which is not confined to sapwood, but may occur in heartwood also. The names "pink dote" and "red dote" are commonly applied to it. This stain appears in the form of terra-cotta or brick-red spots or blotches upon the lumber, varying from a faint to a pronounced colour. In certain cases the stain may penetrate below the immediate surface layers. As a rule it may be readily dressed off, and the strength of the wood is not reduced by the stain.⁵ It is said to be caused by sap-staining fungi, but its origin is not definitely known. This superficial stain should not be confused with the "dote" or "heart rot" of Sitka spruce and other species.

⁵Boyce, J. S. Decays and Discolorations in Airplane Woods. U.S. Dept. of Agriculture, Bull. 1128, 1923.

CHAPTER V

DESCRIPTION OF THE CHIEF WOOD-ROTTING FUNGI OF BRITISH COLUMBIA

General methods for the detection of incipient decay in softwoods have been described in the preceding chapters. For the majority of purposes it is sufficient to be able to detect the presence of incipient or typical decay in wood without attempting to identify the causal fungus. However, for those who are interested in locating the actual fungus present in a piece of decaying lumber, the following brief description of the fungi most frequently found at work in British Columbia softwoods is given. There are many other minor decays in addition to those quoted and the recapitulation should by no means be considered complete.

Fungi Found in Standing Timber

TRAMETES PINI (A White Pocket Rot)

Common names for this rot are red rot, white pocket rot, red heart, conk rot, white honeycomb rot, pecky wood-rot, ring shake, and ring-scale rot. The typical stage is readily recognizable, the wood being honeycombed with small, white pits filled with a light, fibrous mass of cellulose. This rot is very common in Douglas fir, spruce, the pines, and other softwoods, and is easily the most widespread of all wood-rots in North America. It is a trunk rot, and is seldom found in the butt.

Incipient and Typical Stages of Decay

The incipient stages of this rot differ considerably in appearance. In Douglas fir it generally appears as reddish-purple or olive-purple in colour, the colour lessening in intensity as the outer, visible limit of the decay is reached. Sometimes the incipiently decayed area appears brownish against the red or yellow heartwood of fir. Where the incipient decay is merging into typical decay, faint indications of the beginnings of cellulose pits may be seen. The discoloured portion may extend as much as ten feet vertically in advance of the pitted portion, but radially it may advance only a few inches. The reddish-purple discoloration produced by this rot is frequently prominent in the outer heartwood, forming a narrow zone just where it joins the sapwood.

Very rarely the first indications of decay may be in the form of small white or yellow spots or streaks, outlining the initial stages of the formation of the cellulose pits. Such faint indications will often pass unnoticed in a visual inspection.

In Sitka spruce the incipient decay first appears on the yellowish heartwood as a light purple-grey colour, which deepens to a reddish-brown, with the grey forming the outer boundary of the reddish-brown portions. Soon the cellulose pits with their white contents appear.

In Western yellow pine the decay is first noticed as a pink coloration, which soon changes to reddish-brown. The white pits develop afterwards, sometimes quite sparingly. (See plates 27 and 30, pages 121 and 122.)

In Western red cedar there are no identifiable signs of the incipient decay, the first noticeable stage being the appearance of the cellulose pits.

In the final stages of this decay the annual rings may separate, causing a "ring-scaled" condition.

Fruiting Bodies

"Though the perennial fruiting bodies reach a great age—50 years or even more—they are seldom very large, and vary in shape according to the host they grow upon. As a rule, they are irregular, hoof-shaped, the upper side greyish-black, rough, dull, often cracked, with concentric furrows parallel to the rather conspicuous narrow, velvety, light-brown margin. The underside is light greyish-brown. The pores (or spore tubes) are very large and irregular The substance of the fruiting body is rusty-brown in colour, and cuts like cork. On the pines the fruiting bodies grow out through branch scars, and, as a rule, only one or a very few of larger size are developed. On white firs they are generally smaller. On Douglas and white fir they often form directly on the bark, usually in large numbers. Because of their inconspicuous colouring they are easily overlooked."¹

FOMES OFFICINALIS (A Brown Cubical Rot)

Common names for this fungus are chalky quinine fungus, larch fungus, or brown heartwood rot. It is found in standing trees of all soft-wood species, and is one of the few wood rots which are found to directly infect standing trees and manufactured lumber alike. It commonly makes its appearance in bridge work, mine timbers, roofs of factories, etc.

Incipient Stage

The early stages of this rot in most woods are often extremely difficult to detect. Even when the decay has quite well advanced and the wood has already been considerably weakened, nothing may be visible but a faint brownish discoloration.

"The incipient stage of this decay in Western yellow pine appears as a red-brown or pronounced brown discoloration in the pale-lemon to light orange-brown heartwood. The discoloration is not uniform over the entire affected portion, but may occur on the radial or tangential face in broad bands of varying intensity or even intermingled with narrow bands of the normal light-coloured heartwood. In cross-section the wood presents a mottled appearance. The horizontal limits of the discoloration are bounded by a narrow band of pronounced pink or red. At the upper limits of the incipient decay the discoloration becomes fainter until it finally disappears."²

In Douglas fir the incipient decay manifests itself in either of two forms of coloration. The first is a faint reddish or brownish coloration, hard to distinguish, but the second type of coloration is readily visible in green wood. It takes the form of a deep, bluish-purple colour, which gives the wood the appearance of having been soaked in a violet dye. When the wood is exposed to light the colour gradually fades. No other fungus, so far as known, produces this peculiar appearance in Douglas fir. The nearest discoloration in fir which might be confused with it is a dull, bluish to purplish colour which sometimes results from a long period of soaking in water. *Fomes officinalis*, together with *Trametes Pini*, accounts for the greater proportion of the purple or red staining of Douglas fir heartwood. (See plates 27 and 28, page 121, and plate 29, page 122.)

¹Meinecke, E. P. Forest Tree Diseases Common in California and Nevada. U.S. Dept. Agriculture, 1914.

²Boyce, J. S. Decays and Discolorations in Airplane Woods. U.S. Dept. Agriculture. Bull. 1128 1923.

Typical Stage

In the advanced stage of this heartwood decay the wood becomes a brownish-red, crumbly mass, often with conspicuous white, chalky felts of mycelium filling cracks in the wood. In a tree infected with the decay, sheets of the felt may occasionally be found girdling or partially girdling the trunk. These mycelial felts contain a proportion of quinine, as does the fruiting body. Both the incipient and typical stages of this rot are similar to those of *Polyporus sulphureus*.

Fruiting Bodies

The fruiting bodies of this fungus are not very commonly found, but they may be quite large and conspicuous where they do occur. They may be either hoof-shaped or rounded in form, and their surfaces are covered with a chalky powder which easily comes off in the hands when the body is rubbed. The mealy context of the interior has an extremely bitter taste. Spores are emitted from tiny tubes on the convex under-side of the fruiting body.

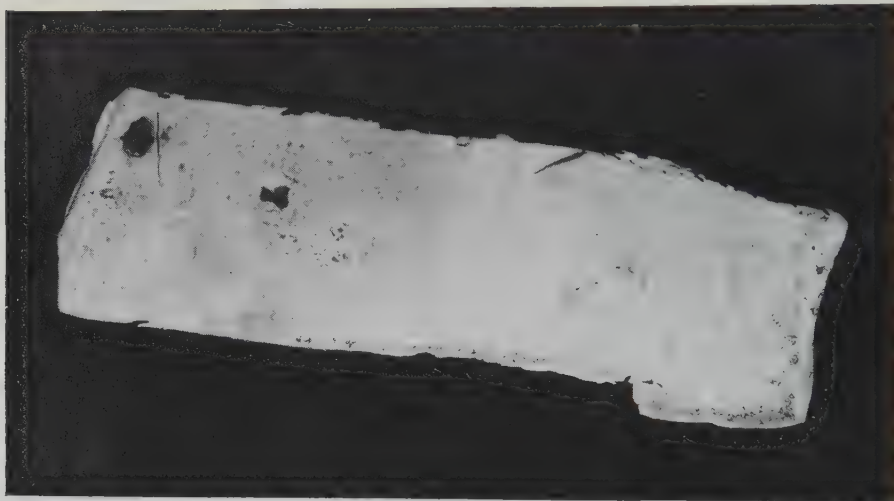


PLATE 34—Mycelial felt of the quinine fungus from a Western Larch

POLYPORUS SULPHUREUS (A Brown Cubical Rot)

Common names for this fungus are "sulphur fungus" and "brown-checked wood-rot." It is more troublesome to hardwoods than to softwoods; among softwoods it is most common in the true firs. The incipient and advanced stages are very similar to those of *Fomes officinalis*.

Incipient Stage

A faint brown discoloration marks the incipient decay, which is, accordingly, difficult to detect. The heartwood is usually attacked first, the sapwood later.

Typical Stage

Completely decayed wood becomes reddish-brown in colour, and resembles charcoal in consistency, so that it can be reduced to powder at a blow. The wood affected splits into cubes, radially and circumferentially, and into the cracks mycelium grows and forms tightly woven sheets.

Fruiting Bodies

The fruiting bodies are distinctive; they take the form of sulphur-yellow, sponge-like, watery, and flaccid knots of irregular shape which may be several inches in diameter. The upper sides of these bodies are smooth, while the lower sides contain spore tubes. They may appear sparingly upon the trunk, or in shelf-like colonies. They soon dry up, shrink, become brittle, and are consumed by insects and bacteria, and, possibly, by other fungi. When young and fresh they are edible.

POLYPORUS SCHWEINITZII (A Brown Cubical Rot)

Common names for this disease are "velvet-top fungus" and "red-brown butt rot." It has not been reported as occurring in hardwoods, but it causes a great deal of damage in softwood timber, being second in importance to *Trametes Pini*. The two rots are often found in the same tree; *Polyporus Schweinitzii* in the butt and roots, and *Trametes Pini* in the upper trunk and branches. *Polyporus Schweinitzii* is characteristically a butt rot, and is hardly ever found in the upper parts of the trunk. Often the roots and butt become so weakened by this fungus that the tree is easily overthrown by wind. (See plate 35, page 123.)

Incipient Stage

In Sitka spruce the fungus first appears in the form of pale yellow streaks, extending in a longitudinal direction, which later develop to a deeper yellow or reddish-brown discoloration. When the colour has deepened thus far, the wood is appreciably softer.³

In Douglas fir the incipient decay produces a faint yellowish or brownish discoloration in the heartwood.

Typical Stage

In its typical stages the wood becomes distinctly yellowish, and soon splits into cubical, soft, and cheesy masses. Finally it becomes uniformly rotted, crumbly, and red-brown in colour. Mycelial felts occur, but they are fine and inconspicuous, and not nearly as thick as those which commonly occur with *Fomes officinalis* and similar fungi.

Fruiting Bodies

These are soft, red-brown, umbrella-shaped structures with a central stalk and circular, somewhat wavy top. They sometimes grow to a large size—as much as one foot in diameter across the top. Spores are produced in tubes on the under side of the fruiting body. "It continues to live and produce spores long after it has killed its host, and thus is a serious enemy to standing timber" (Meinecke).

Fruiting bodies are not often found; they are annual, and seem to be attractive to birds, small animals, and insects, which eat them. They are more likely to be found growing in the soil some distance away from the roots of the tree than upon the tree itself; in this event they have a short, thick stalk.

³Boyce, J. S. Decays and Discolorations in Airplane Woods. U.S. Dept. Agriculture. Bull. 1128, 1923.

ECHINODONTIUM TINCTORIUM (A Brown Stringy Rot)

Common names for this fungus are "Indian paint fungus," "stringy brown rot," and "stringy red-brown heartwood rot." It is prevalent amongst the true firs (balsams), and is very severe on Western hemlock, causing probably the bulk of fungous damage to this species. It also occurs occasionally in Douglas fir.

Incipient Decay

In true fir the incipient stages are marked by light-brown or golden-tan spots or larger areas on the tangential face of heartwood, accompanied by small burrows similar to a shallow insect-boring, extending in a radial direction.

In Western hemlock the incipient decay is harder to detect because the colour produced by it is very similar to that of the normal wood. The wood first becomes a yellowish colour, which intensifies later to a brownish colour, and then produces the typical decay.⁴

Typical Stage

Often rusty red streaks are found following the line of the grain, and at this stage the wood has been greatly weakened. As the discoloration deepens the wood becomes softer and finally is a brown, fibrous, stringy mass.

In growing trees or in logs the rot can be identified by the rusty knots or branch stubs through which the fungus has gained admittance to the heartwood. It may eventually rot away the whole of the heartwood, leaving the tree hollow, so that only a thin sheet of sapwood remains.

Fruiting Bodies

These usually form at branch wounds or knots, range from a few inches to a foot or more in width, and are hoof-shaped bodies, grey or black on the upper surface, with many large and firm straw-coloured or greyish spines on the under surface. Spores are borne on the outside of these teeth or spines. In younger specimens the upper surface is lighter in colour and the lower surface is grey to white, honeycombed with pores, which later turn into spines.

The interior of the body is a bright, rusty red, containing a pigment formerly used by Indians for the making of red war-paint. Fruiting bodies develop on the middle of the trunk and are quite abundant.

FOMES PINICOLA (A Brown Cubical Rot)

Common names for this fungus are "red-brown sapwood rot" or "belt rot." It is very prevalent in British Columbia and commonly attacks Sitka spruce, the pines, Western larch, Douglas fir, and Western hemlock; it also attacks certain hardwood species. It is more often found in dead standing trees or logs than it is in living trees, and in the Coastal region at least this fungus is the chief destroyer of forest debris in the form of "down" timber or unused logs. Vigorous, healthy, standing trees are rarely infected by it. (See plate 36, page 123.)

⁴The description of incipient decay produced by this rot in true fir and Western hemlock is taken from Boyce's bulletin: Decays and Discolorations in Airplane Woods: U.S. Dept. Agriculture. Bull. 1128, 1923.

Incipient Stage

In the first stages of decay the wood shows, in longitudinal section, grey-white, irregular spots or streaks with reddish-brown centres. In Douglas fir, which it commonly attacks, the fungus produces only a faint yellow discoloration, irregularly defined, which is extremely difficult to detect.

Typical Stage

As the decay spreads the wood separates into cubical, cheesy, easily pulverized sections with checks and cracks running in all directions, filled with thin, white, felty masses of mycelium. The felts are not so conspicuous nor so large as those of *Fomes officinalis* (*F. Laricis*).

Fruiting Bodies

These are abundant, and are the most conspicuous of the conchs or brackets found in the forests of British Columbia. On living trees the fruiting body is generally hoof-shaped, with a brownish-black upper surface, and a creamy-white lower surface, the latter containing innumerable tiny spore-tubes. The margin is a chestnut-brown, bright colour, resembling an application of paint or varnish. The interior of the fruiting body is tough and woody. On down trees and logs the sporophore is usually in the shape of a bracket, with flattened or convex surfaces, and with similar colorations to the other form. The fruiting bodies are perennial, and add growth to themselves year by year.

FOMES ROSEUS (A Brown Cubical Rot)

This fungus is called the "rose-coloured fomes," or "brown-pocket heartwood rot." Infection seems to take place commonly at dead tops, and the rot is mainly confined to the upper portion of the trunk. It is most common on Douglas fir, but has been found to occur on most conifers and some hardwoods. In prostrate trees and logs it attacks sapwood as well as heartwood. Its effect upon wood is similar to that produced by the fungus *Polyporus Schweinitzii*.

Incipient Stage

At first this rot forms elongated pipes or pockets of decay in the wood, pink to red-brown in colour, the depth of colour depending upon the natural colour of the infected wood.

Typical Stage

As the decay progresses, the pockets enlarge and combine with adjacent pockets, forming larger regions of decay. The wood shrinks, becomes soft and crumbly and split up into cubical pieces, pink to red-brown in colour. Fine, inconspicuous, mycelial felts are sometimes seen.

Fruiting Bodies

These are perennial, and are of two kinds, according to whether they are found on standing trees or prostrate timber. In the former case they take the shape of brackets, rather hoof-shaped and thick; in the second case they are usually thin and shelving. The upper surface may become black with age, while the margin and the lower surface are somewhat pink. The interior of the fruiting body is pink in colour. Spores are expelled from minute pores on the lower surface of the fruiting body.⁵

⁵ Hedgecock, G. G. in *Phytopathology*; Vol. 4, No. 3 (1914)

FOMES ANNOSUS (A White Pocket Rot)

This is a root and butt rot. All conifers are occasionally attacked by it, but it is not as important as certain other western fungi, or nearly as prevalent as it is in the eastern part of the continent, or in Europe, where it does a great deal of damage.⁶ It is hardly ever found in hardwoods. In conifers with a low resin content the decay may spread upward in the trunk for several feet, but in resinous conifers the rot is confined to roots and butt. A pronounced resin flow from the butt and roots of decayed trees is characteristic.

Incipient Stage

The early stages of the rot seem to vary with different hosts, but the sapwood generally rots first. The first sign of the rot is usually a bluish discoloration, which changes to a dirty yellow and finally becomes brown or red-brown.

Typical Stage

Small, elongated, white pits filled with celluline material appear, similar to those caused by *Trametes Pini*, but more irregular in shape; these pits may have black spots in their centres. In the final stages of decay the wood may be thoroughly honeycombed by these white pits.

Fruiting Bodies

These are to be found among the roots, either upon them, or, more often, as ectotropic growths upon the roots under the surface of the soil. They are narrow, long, shelving bodies, and have a light-yellow or tan-coloured upper surface and a nearly white or light yellow under-surface. Spores are expelled from pores on the outer or lower surface of these bodies.

POLYPORUS ELLISIANUS (A White Pocket Rot)⁷

Other names for this rot are red-ray wood-rot, red heart, red-rot, grey-rot, and top-rot. It is prevalent in Western yellow pine, and attacks both sapwood and heartwood of living trees of this species.

Incipient Stage

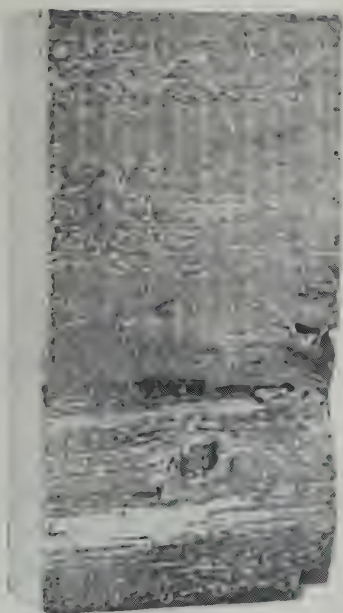
Infection occurs usually at old branch wounds at the top of the tree, whence it spreads, often producing a rotted portion 12 to 20 feet long from a single infection. At first the heartwood shows reddish to dark-brown discoloured areas.

Typical Stage

In Western yellow pine the typical stage of this rot turns the wood a grey or nearly white colour, and it can be easily pulled apart. The rotten wood consists of soft white strands or pockets of celluline material, intermixed with less rotted wood. The little pockets of cellulose resemble those of *Trametes Pini*, but have blunter ends, and are wider than the latter. At this stage the wood is often so wet and soggy that water can be squeezed from it. (See plate 37, page 124.)

⁶This fungus is mentioned as occurring in the West by E. P. Meinecke (Forest Tree Diseases Common in California and Nevada), W. H. Rankin (Manual of Tree Diseases), and J. S. Boyce (Deterioration of Wind-thrown Timber on the Olympic Peninsula. U.S. Dept. Agriculture, Tech. Bull. 104, 1929).

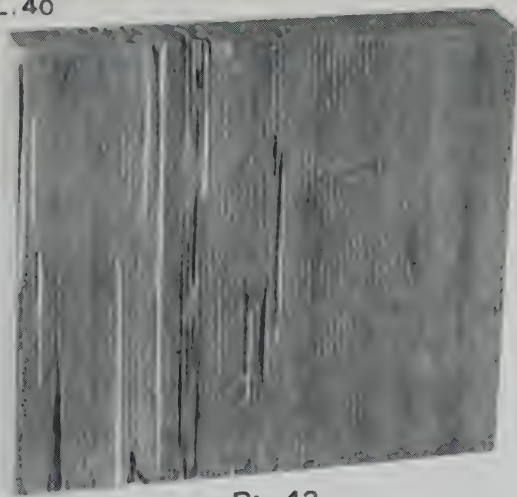
⁷See U.S. Dept. Agriculture, Bull. 490. (Long, W. H.: Preliminary Report on the Occurrence of Western Red-rot in *Pinus ponderosa*.)



PL.40



PL.41



PL.42

PLATE 40—*Poria subacida* in True Fir (*Abies* sp.)

PLATE 41—*Fomes roseus* in Douglas Fir
Note brashy condition of wood. (Reduced to about half size)

PLATE 42—A common rot in Western Red Cedar
Causal fungus unknown. Note the hollow pipes in the wood. (Reduced to about half size)

The rot may be rapid in its action, as it develops radially almost as rapidly as it does longitudinally. Radiating from a decayed region are narrow red-brown rays of rotted wood, extending like the spokes of a wheel towards the bark; these red rays have a white core of completely decayed tissue. From these radial patches the rot spreads in all directions, until finally the entire heartwood is affected.

Fruiting Bodies

These are in the form of white, flat, annual, encrusting layers, usually found on the surface of logs lying on the ground. Fruiting bodies are seldom found on standing trees.

GANODERMA OREGONENSE (A White Pocket Rot)

This fungus operates along the Pacific coast from California to Alaska, occurring in Sitka spruce, Douglas fir, and Western hemlock. It is most often a heartwood rot.

Incipient Stage

In the early stages the wood bears a dark, sodden appearance, commonly referred to as "water-soak." When this portion dries out the wood evidences little or no visible sign of decay.

Typical Stage

In the later stages of decay the spring-wood is reduced to a thin, almost indistinguishable cellulose layer; later the summer-wood is involved in the same decay. The wood separates into thin sheets, showing a light, spongy, straw-coloured rot, with numerous large, black spots and ramifying black lines.

Fruiting Bodies

These are of the bracket type, heart-shaped or kidney-shaped, with a stout stalk almost as long as the fruiting body is wide; they are either annual, or may persist for several years. They have a conspicuous, mahogany-coloured or almost black, shiny, varnished upper surface, and the lower side is brown. The interior of the fruiting body is composed of a spongy mass of interwoven threads, more or less pulpy, white or cream in colour.⁸

PORIA WEIRII (A Brown Ring Rot)

This fungus is responsible for probably the greater part of the butt rot in Western red cedar. It has not been reported so far in other species.

Incipient Stage

The early stage produces a yellow discoloration, not readily discernible. The spring-wood of each annual ring decays first, producing a laminated or stratified appearance.

Typical Stage

The final stage is a brown crumbly rot, with thin webs of brownish mycelium between the laminations.

⁸Notes provided by Dr. J. W. Hotson, of the University of Washington, and Dr. F. Dickson, of the University of British Columbia, have been utilized in writing the description of this rot.

Fruiting Bodies

These are flat, irregularly shaped, perennial encrustations, quite thick, and brown in colour. They are most commonly found in root crotches of Western red cedar.⁹

Fungi Found in Down Timber and in Lumber

The foregoing rot-producing fungi are characteristically parasitic upon living trees and seldom directly infect manufactured lumber. The majority of the rot defects with which the lumber grader has to deal are produced in the living tree, but any description of the rots of softwoods would be incomplete without reference to the rots of softwood structural material, some of which are very destructive and wide-spread. The remainder of this chapter, therefore, is devoted to a description of those wood-rotting fungi which preferably attack only felled or dead timber or manufactured lumber.

Rots in either group may continue to develop in lumber (but not in lumber which has been kiln-dried) when it has been placed in position, provided that conditions are favourable. Rotations which are at work in the standing tree cannot be checked by any known artificial means as long as the tree is standing, but the progress of rots at work in manufactured lumber can be checked by suitable methods of handling, storage, and utilization.

The original infection of lumber which is in storage or in position may take place by means of *spores* or *mycelium*. When fresh spores (produced by fruiting bodies or mycelium) settle upon moist wood a number of them germinate in much the same way as seeds would in the soil, and soon produce mats of mycelial threads in and on the wood. If lumber which is sound (i.e., free from decay infection) is placed in contact with decaying timber, threads of mycelium are likely to grow directly from the infected to the sound stock, and in a moist, warm atmosphere they may even overgrow inert substances such as rock and masonry and reach sound wood some distance away. When wood is placed in contact with the ground infection may come directly from the soil, which harbours many destructive fungi.

The rots of structural timber are often loosely included under the heading of "dry rot," but this name is correctly applicable only to a limited number of rots (see Chapter III).

DRY-ROT FUNGI

The true dry-rot fungi comprise *Merulius lacrimans*, *Poria incrassata*, and some others of the *Poria* genus. These fungi are not confined to this region, but are found in all parts of the world. They seldom occur in hardwoods, but may attack both heartwood and sapwood of softwoods, especially sapwood. (See plate 38, page 124.)

Both *Merulius lacrimans* and *Poria incrassata* are frequently found growing in timber without any apparent moisture supply, but in reality they cannot grow without moisture. Given moist wood in which to germinate, these fungi are able to make their way a surprisingly long distance in dry timbers, drawing the water they need from the moist wood through a conduit system of slender, root-like, minutely porous strands, which run over the surface of the wood, and may weave themselves into cord-like strands or thin skin-like sheets. By means of these superficial threads, which are known to the pathologist as *rhizomorphs*, the fungi can advance

⁹ See Murrill, W. A.: in *Mycologia*, Vol. 6 (1914), pp. 93-94.

over innutritious substances such as brick walls, masonry, and steel wires, and the infection can in this way be transmitted to distant woodwork, when the fine threads of the typical mycelium ramify through the interior of the wood substance and decompose it.¹⁰

Wood-destroying fungi are in reality living plants, and like all forms of life naturally favour the best conditions which environment may permit for their rapid development and propagation. A situation where the atmosphere is damp, which is unventilated, free from bright light, and with no extremes of temperature, is very suited to the growth of fungi, and may be found underneath lumber piles, in damp storage sheds, in obscure, damp corners of dwellings and buildings, in mines, and in similar locations. Such situations are very suitable for the growth of fungi, so that they often are not confined to the interior of the wood, but grow into the air, forming matted, fine webs, or little, white, fluffy tufts (see Fig. 16). When these growths are found upon the surface of damp wood, one may be sure that infection is well under way in the wood. Such occasionally prolific, extraneous growth of hyphae is found not only with the "dry rot" group, but with many others of the common wood-destroying fungi. The tufts of mycelium will often grow and spread in extent, merging into each other and forming an irregular-shaped patch. This patch weaves itself, as the disease progresses, into a thick, compact mass of hyphae, spreading over the timber for a considerable distance, and in some cases throwing out cords or roots for the conduction of moisture. Flattened fruiting bodies of this nature occur with fungi of the genus *Poria*, *Merulius lacrimans*, and *Coniophora cerebella*.¹¹ Some of these flat growths are white in colour, some various shades of green or yellow, having on their faces numerous small pores, circular in shape, or approximately so, through which spores are emitted. The conductive strands of *Merulius* are of an ashy-grey colour, while the strands of the *Poria* are generally pure white or nearly white.

The first stages of dry rot produce a yellowish-brown discoloration not readily discernible. Often the appearance of the wood changes little until the later stage of decay is reached, and the wood becomes brownish in colour, or may present a dirty appearance, stained with red or brown streaks. At this stage infected boards seem dull and lifeless, and produce a dull, hollow sound when struck with a hammer. Finally, the wood begins to crack, check, and warp. Cubical shrinkage cracks appear, filled with thin, waxy sheets of mycelium, and the shrunken wood may assume a burnt or scorched appearance. Eventually it becomes so brittle that it may be readily crushed to a powder.

The so-called "dry rot" in buildings in this country is more often due to other wood-rotting fungi than to the true dry rots. Commonest of the wood-destroying fungi in buildings, structural timbers, and stored lumber are *Lenzites sepiaria*, *Lenzites Berkeleyi*, *Lenzites abietina*, *Schizophyllum commune*, *Lentinus lepideus*, *Stereum fasciatum*, *Stereum lobatum*, *Polydictus abietinus*, *Coniophora cerebella*, and *Fomes officinalis* (*Fomes Laricis*).

Fomes officinalis, although frequently found at work in structural timber, does not fall in the same category as the above group, as its real habitat is in standing timber (see p. 75).

¹⁰For a description of the work of these two fungi, see Humphrey and Miles's bulletin: Dry-rot in Buildings and Stored Construction Materials, and How to Combat It, Ala. Poly. Inst. Circ. 78 (1925).

¹¹This fungus has also been called *Coniophora puteana* (see Humphrey, C. J., Timber Storage Conditions in the Eastern and Southern States. U.S. Dept. Agriculture, Bull. 510. 1917.)

LENZITES SEPIARIA (A Brown Cubical Rot)

Lenzites sepiaria is prevalent in untreated coniferous railway ties and telegraph and telephone poles, and one-fourth of the great fungal damage done to these structures is said to be due to this fungus.¹² There are also vast quantities of timber in the form of piling, bridge timber, trestles, sidewalks, fence-posts, etc., which are destroyed by it. It rarely attacks living trees and is more often a saprophyte, attacking timber piled for seasoning, or which is in use but exposed to the elements, often entering the wood through season cracks. This fungus and *Lenzites Berkeleyi* (a very similar fungus) are estimated to be the most serious enemies of coniferous structural timber in North America.

Incipient and Typical Stages

In the early stages of decay the infected wood is darker in colour than the normal wood. In the later stages of decay the wood becomes brown in colour and is eventually easily reduced to an amorphous powder, a similar effect to that produced by *Merulius lacrimans*. Sometimes the spring-wood in the annual rings rots first, leaving a laminated rot in which the wood separates along the annual rings. Small cracks run irregularly across the wood fibres, indicating that considerable shrinkage has been caused by the action of the fungus on the wood. The sapwood is most seriously affected by the rot, but in time the heartwood also becomes affected.

Fruiting Bodies

Development of this fungus is rapid under favourable conditions, and fruiting bodies have been seen to develop in green lumber in the space of five months. They are small bodies, rarely projecting more than two inches from the surface of the wood or log, and are commonly long, narrow, shelf-like formations, extending horizontally from the surface of the wood. They are frequently compound or clustered very closely together, and are especially numerous on the ends of affected timbers. Usually the fruiting surface has irregularly or regularly branching gills, but occasionally they have more or less regular pores. Sometimes the fruiting surface may be in the form of spiny projections.

The sporophore is perennial. It varies greatly in colour, depending upon its age. The youngest bodies are white; then, as their age increases, the colour turns rapidly to yellowish-white, then to deeper yellow, then to brown, and in very old specimens it may be almost black. These bodies may remain dry and apparently lifeless for a long time, yet still be able to produce viable spores under favourable conditions.

CONIOPHORA CEREBELLA (A Brown Cubical Rot)

This fungus does not seem to require as abundant moisture supply as the majority of wood-inhabiting fungi, hence is often included in the "true dry rot" group. It differs from the "true dry rots," however, in that it does not produce the thick conductive strands of *Merulius* and *Poria incrassata*, and requires more moisture than they. The sapwood is usually attacked first, and in favourable situations pieces of coniferous timber may be completely rotted by this fungus within the short space of a year. Hardwoods are also attacked by it. Its effect upon the wood is similar

¹²Spaulding, P. Timber rot caused by *Lenzites sepiaria*. U.S. Dept. Agriculture, Bull. 214, 1911.

to that produced by *Lenzites sepiaria*, *Lentinus lepideus*, and *Merulius*. First the wood merely darkens in colour; then it becomes brown and soft, and finally is easily crushed between the fingers.

The fruiting bodies are flat incrustations resembling those of *Merulius lacrimans*; they are, however, not so gelatinous. In some situations they are smooth, very thin, and membranaceous; at other times the surface is warted, or convolute.

SCHIZOPHYLLUM COMMUNE (A White Rot)

This fungus is widespread in both softwoods and hardwoods. The fruiting body "is white to greyish, very thin and flexible, woolly above, and has very distinct gills below, which are split longitudinally at the edge and each half curled over, much as a dandelion stem curls when split. It is a comparatively small fungus, usually not projecting out more than one or one and one-half inches. At times it is attached at the centre of the back and then presents a circular outline with the gills radiating from a common centre. When dry it is much curled and inrolled, but during rainy weather it readily revives and appears fresh and expanded again."¹³

Although wide-spread, the fungus damages lumber only slightly and its effect is not so serious as that of others in the group.

LENTINUS LEPIDEUS (A Brown Cubical Rot)

"This is a fungus of the toadstool type, with a circular, broadly convex, scaly cap, and a stout, fibrous, central or eccentric stem. It is white throughout, except for the brownish scales on the upper side of the caps and on the stem. The under side has coarse gills, which become considerably toothed and split as the plant ages."¹⁴

It primarily attacks timber in contact with the soil, and can rot softwood railway ties rapidly, spreading from one tie to another through the soil. It also frequently occurs in warehouse floors, and in lumber-storage yards. It produces a brown, cubical, crumbly rot, similar to that caused by *Lenzites* and *Merulius*.

STEREUM FASCIATUM and *STEREUM LOBATUM* (White Pocket Rots)

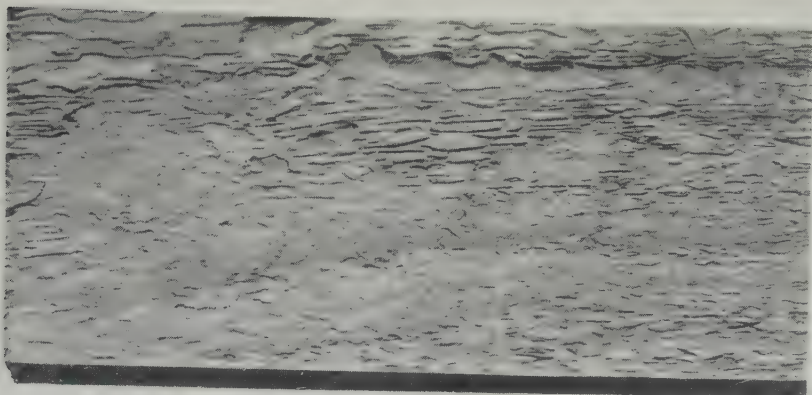
These two are very similar in appearance; their fruiting bodies are small shelves or brackets, with a smooth lower surface and a roughly corrugated top. They are very thin and flexible, the individual shelves growing one above the other, and their colour is greyish to creamy.

Distinct pockets are formed in the wood, irregularly developed, in both spring- and summer-wood, usually containing cellulose fibres. Black spots or flecks are often found in the decayed areas.

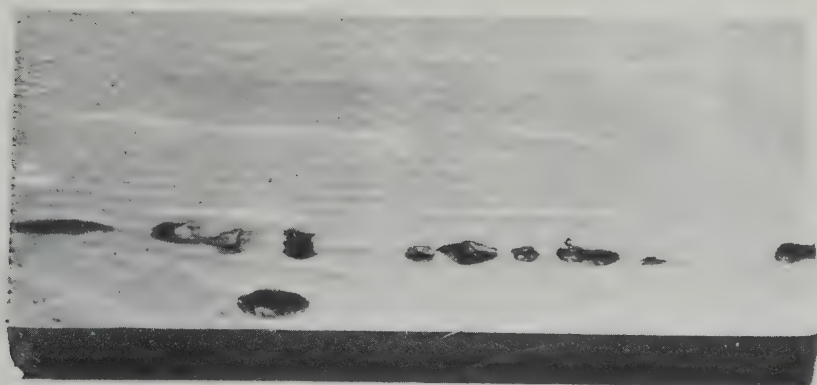
Stereum is prevalent in dead and down timber, particularly Western hemlock, as well as in structural timbers.

¹³Extract from Humphrey, C. J. Timber Storage in the Eastern and Southern States, U.S. Dept. Agriculture, Bull. 510, 1917.

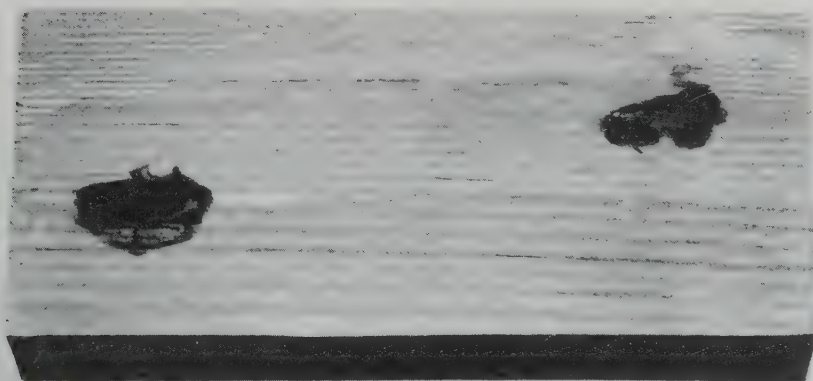
¹⁴Extract from Humphrey, C. J. Timber Storage in the Eastern and Southern States. U.S. Dept. Agriculture, Bull. 510, 1917.



PL.43



PL.44



PL.45

PLATE 43—*Polystictus abietinus* in Hemlock

PLATES 44 AND 45—"Peckiness" in Western Red Cedar

POLYSTICTUS ABIETINUS (A White Ring Rot)

This fungus is frequently found in lumber yards, occasionally on stored lumber, but more often in timbers, foundations, and ties. It is also common in the sapwood of dead coniferous trees, whether down or standing, and prefers sapwood to heartwood.¹⁵ Small, shallow, narrow, numerous cavities are formed in the wood, separated by thin partitions of sound wood. Frequently the cavities are confined to one plane, causing the rings to separate. In the final stages of decay the wood is very spongy.

The fruiting bodies are small, shelving brackets with pores on the lower sides.

¹⁵See Humphrey, C. J. Timber Storage Conditions in the Eastern and Southern States with Reference to Decay Problems. U.S. Dept. Agriculture, Bull. 570, 1917.

CHAPTER VI

DURABILITY OF SOFTWOODS

The durability of wood refers to its ability to resist deterioration in service—such deterioration being caused by mechanical wear, exposure, fire, or the attacks of certain forms of marine and land life. The natural durability of wood usually refers to its ability to resist attacks of wood-destroying fungi under conditions which favour the growth of these organisms, as in wooden structures placed in or upon the ground, in mines, in house basements, and similar structures. Natural durability contrasts with artificial durability; the latter is attained by the use of preservatives.

The durability of the various softwood species differs; but there is little scientific information available upon the comparative longevity of softwoods when exposed to conditions calculated to produce decay. Absolute comparisons can be made only as a result of carefully regulated service conditions extending over a lengthy period of time, and up to the present no such series of tests of British Columbia softwoods has been made, so that for guidance as to the relative durability of native species it has been necessary to use durability standards borrowed elsewhere.¹

Although certain softwood species show a greater durability than others, there may be considerable variation among individual members of a species, or even among sticks cut from an individual tree, and unless other factors, such as warmth and moisture (especially moisture), are taken into consideration, comparisons are frequently misleading. For example, although Western red cedar is considered more durable than Western white pine, it is quite possible for a fence-post made from the latter to outlast one made from the former, even in the same line of fence; and a piece of true fir is just as durable as a piece of Western red cedar, if kept quite dry, or if kept submerged in water, both specimens lasting indefinitely under such conditions.

Current researches into this subject indicate that the presence or absence of infiltrated toxic materials, such as tannins, oils, etc., is the most important factor in determining whether or not a species is durable. Artificial preservative processes, where preservative oils, etc., penetrate the wood, are nothing more or less than a simulation of nature's process of wood preservation. The presence of these toxic substances generally deepens the colour of the wood, and dark woods are usually more durable than light woods, but colour is not a safe guide to durability, as exceptions occur. Heartwood contains more of these toxic materials than sapwood,

¹The following information upon relative durability was issued by the United States Forest Products Laboratory, Madison, Wis., in June, 1928:—

"General comparisons of the relative decay resistance of different species must be estimates. They cannot be exact and they may be very misleading if understood as mathematically accurate and applicable in all cases. They may be very useful, however, if understood as approximate averages only, from which specific cases may vary considerably, and as having application only where the wood is used under conditions which favour decay. The following classification of common native species is subject to the limitations mentioned above.

"From service records where available, supplemented by general experience, the heartwood of the following species may be classed as durable even when used under conditions which favour decay: . . . Practically all of the cedars, . . . and Pacific yew. Similarly the heartwood of . . . the true firs (not Douglas fir) . . . when used under conditions which favor decay may be classed as low in decay resistance, while the heartwood of Douglas fir . . . western larch . . . may also be classed as intermediate. The heartwood of dense Douglas fir . . . may also be classed as intermediate but nearly as durable as some of the species named in the high-durability group. The heartwood of . . . the hemlocks, . . . and the spruces may be considered on the border line between the intermediate and non-durable groups and cannot with assurance be placed wholly in either group."

and is consequently darker in colour and more durable than sapwood. The unseasoned heartwood of softwoods always contains a lower percentage of moisture than the sapwood, and this gives it additional advantage from the point of view of decay resistance. Unseasoned sapwood, furthermore, contains abundance of soluble carbohydrate food suitable for the nourishment of wood-destroying fungi, whereas this is lacking in the heartwood. In softwood logs which have floated in water for a time some of this soluble food material is undoubtedly leached out; this forms the reason for the "pickling" of logs and lumber that is in vogue in several parts of the world, but the exact extent to which such immersion increases durability is not known.

Wood of any species containing incipient decay when placed in position is unlikely to be durable. For sterilization of incipiently decayed wood, the dry-kiln is an effective medium; practically all fungi which may be found in wood are killed by application of heat in the course of kiln-drying, so that the wood can only decay further when it has been re-infected from some exterior source. If the moisture content of the wood be reduced by air-drying, the risk of fungal attack is lessened. If air-dried wood re-absorbs a sufficient quantity of moisture, however, any fungi present in the wood are likely to grow. These remarks particularly apply to lumber used in structures exposed to the weather.

The manner in which wood is manufactured has a bearing upon its durability. Tangential shrinkage in all woods is greater than radial shrinkage, so that pieces containing the pith (boxed heart) check and warp more in seasoning than pieces which do not contain the pith. Again, dense specimens shrink and check more than pieces of uniform growth and density. Wood-destroying fungi enter through these checks, and moisture is readily admitted to the interior of the piece. Untreated, dense specimens with a boxed heart, therefore, should be excluded from use in situations of exposure to the weather, as in sills, stringers, posts, etc., whenever possible, or premature decay is likely to result.

For similar reasons edge-grain boards or shingles are likely to be more durable than flat-grain boards when exposed to the weather. The surfaces of flat-grain boards are liable to "raise" and present a "feathered" appearance after drying and exposure; at these raised places moisture may collect, and fungi gain easy admission. Where the edge-grain material is subjected to wear and tear, as in flooring and wood paving-blocks, it has the additional advantage of being able to resist abrasion, the hard bands of summer-wood protecting the surface.

The shrinkage factors of a species have an important effect upon its durability. They largely determine the response of the material to climatic conditions, and the amount of "weathering" it sustains during its period of use. Local conditions, such as climate, character of the soil, drainage, and type of ground-cover, are also important because they affect moisture, air circulation, and temperature.

Briefly, therefore, in order to determine whether or not an individual stick of untreated lumber will be durable, one must consider:—

1. To what use it is to be put, and how much moisture it is likely to absorb;
2. Whether it is from a durable species or not;
3. Whether it contains sapwood or not;
4. Whether or not it contains incipient decay;
5. Whether air-dried or kiln-dried.

Presence of Resin and Durability

Species which contain much oil or resin—e.g., Douglas fir, Western larch, Western red cedar, and yellow cedar—are generally durable. Whether this is merely coincidence, or whether the presence of resin in itself makes for durability, is uncertain. The hyphae of fungi have been noticed by various observers to actually penetrate resin in wood, and resin in itself has no toxic effect upon fungi. Resin has a waterproofing effect, and by preventing imbibition of moisture may discourage the growth of wood-destroying fungi, but the wood must be well saturated with resin to produce a waterproof effect sufficient to prevent decay.²

Durability of Sawn and Hewn Ties

The claim is often made that hewn ties are more durable than sawn ties, because they shed water better, but there is little or no evidence to substantiate this claim. The surmise that an axe closes the pores of the wood severed by it, while a saw does not, has no reasonable foundation in fact; neither is there ground for supposing that a sawn surface holds moisture, while a smooth, hewn surface does not; the axe-marks and other depressions on the uneven surface of a hewn tie provide more receptacles for the retention of moisture than the saw-fuzz does.

Hewn ties usually contain more sapwood than sawn ties. Untreated hewn ties, therefore, are more liable to decay than sawn ties, while in treating hewn ties the sapwood may absorb the greater portion of the preservative and leave the hewn surfaces virtually unprotected. The quantity of preservative needed for the average sawn tie is less than that needed for the average hewn tie, because it contains less wood volume and less sapwood.

Other considerations of practical importance sustain the superiority of the sawn tie over the hewn tie.

Charring of Posts and Poles and Durability

Theoretically a layer of charcoal about a post or a pole prevents decay, but in actual practice the process of charring often causes cracks or checks into which the spores of fungi can enter. If seasoned posts are charred the fire may not reach the bottom of the checks already present, while if unseasoned posts are charred checks will open up as the wood dries out. A post of ordinary dimensions, charred deeply enough to resist decay effectually, would be greatly weakened and would prove much less suitable for service than an uncharred post.

Comparative Durability of Lumber from Dead and Living Trees

It is sometimes claimed that lumber from a living tree is more durable than that from a dead tree. It is impossible to give a general statement in this connection which will hold good in all cases, because of the numerous exceptions which may occur. A dead tree often owes its death to the attacks of wood-destroying fungi, hence lumber from such a tree may contain incipient or typical decay; but not all dead trees have been killed as a direct result of fungous attacks. On the other hand living trees may

²Zeller, S. M. Relation of Resin to Durability of Southern Pine. Am. Rlwy. Eng. and Maintenance-of-Way Assn., Vol. 19 (1917), No. 198.

sometimes be infected by fungi, hence there can be no guarantee that lumber from a living tree does not contain wood-destroying fungi. It is quite possible for clear lumber from dead trees to be just as sound as similar lumber cut from living trees.

Colour as an Index of Strength and Durability

There is a wide-spread opinion that with certain woods the darkness of colour of the heartwood is an index of the strength of the piece, also that the darker the heartwood, the greater is the durability. These standards are of very doubtful accuracy.

Seasonal Cutting and Decay

It is doubtful whether lumber cut in winter differs in its subsequent durability, or its mechanical strength, from lumber cut in spring or summer; there are, however, certain external factors which relate to the durability of winter-cut wood.

The activity of wood-inhabiting fungi is halted or retarded in winter, and the spores (which may be resting upon the wood, seeking opportunity to germinate) or fungal mycelia (which may be present in the wood) are not likely to develop, but remain dormant during this period. By the time warmer weather arrives in the spring, and the fungi are ready to renew their period of greatest activity, the surface of the wood has dried out sufficiently to prevent external infection from taking place, and fungal activity is largely confined to the inner section of the log. Winter-cut lumber, therefore, is not as liable to sap-stain or decay infection, during the period between cutting and seasoning, as lumber cut at other seasons of the year.

If the inner portion of the log remains moist (as is likely), and contains a wood-destroying fungus, this will continue development as soon as weather conditions are favourable. At all times of the year, therefore, it is a good plan to manufacture and season the lumber as soon as possible after it has been cut, in order to minimize the chances of decay infection and development. The care which the lumber receives after cutting is of much greater consequence than the time of the year at which it is cut.

Seasonal Cutting and Insect Attack

Logs cut in the late spring and early summer are liable to be attacked by insects, because the wood is then in a favourable condition for attack at a time when insects are most active.

If the lumber is peeled when cut and piled openly on skids, opportunity for decay and insect attack is greatly reduced; peeling can best be done in the spring. In no case should logs be allowed to remain in direct contact with the ground over a period of months.

Seasonal Cutting and Checking

Air-seasoning proceeds most rapidly during warm weather, and therefore may cause excessive checking in the summer months, which damages the lumber and in some cases induces subsequent decay.

Timber cut in late fall and winter seasons more slowly and with less checking than timber cut during the warmer months, and, where proper means of storage and handling of logs and lumber are not available, winter cutting is preferable.

CHAPTER VII

DEFECTS CAUSED BY INSECT AND MARINE LIFE

Insects

In the United States the annual loss in standing timber from insect depredations is computed at \$105,000,000, and loss from the same cause in forest products at \$45,000,000, giving a total annual loss of \$150,000,000 in timber and timber products.¹

No authentic figures are available of the annual damage from insect pests in British Columbia, but it is known to be heavy. Most of it is due to bark-beetle activity in yellow pine, white pine, lodgepole pine, and Douglas fir. Losses in lodgepole pine, Western yellow pine, and white pine are severe, due to the combined attacks of the western pine beetle (*Dendroctonus brevicomis*, Lec.), and the mountain pine beetle or Western white pine beetle (*Dendroctonus monticolae*, Hopk.). Insect pests in timber are of three main classes, namely, defoliators, bark-beetles, and wood-borers.

Defoliators injure or kill large quantities of standing timber by eating off the leaves and needles during one or more years. Where defoliating insects do not kill trees, they frequently retard growth over large areas of forest land, so that the loss in timber volume becomes a matter of considerable economic importance. As their activities are confined to foliage, they do not produce lumber defects. Among the defoliating insects of British Columbia are such destructive pests as the spruce budworm, the larch sawfly, the western hemlock looper, and the Douglas fir tussock moth.

Bark-beetles of the genus *Dendroctonus* cause by far the greater part of the insect damage to standing timber. As a rule they breed most freely in dying trees, windfalls, stumps, trees injured at the base by fire, and culled logs; but when they are numerous and epidemic they readily attack living, healthy trees of large size. They mine the inner bark with innumerable galleries, eventually "girdling" the tree and killing it. They are everywhere present in the forests of British Columbia, but normally various natural agencies hold them in check, restricting their depredations to an occasional tree, and foresters are usually satisfied if attacks can be kept down to this normal or endemic condition. As soon as an epidemic is detected, prompt control measures are necessary to save the timber; otherwise ninety-five per cent or more of an infested stand may be rendered unmerchantable in the course of a few years. Control measures consist of burning slash and debris in the woods, and cutting down, peeling, and burning the bark of infested trees in the spring, when the insects are still in the larval, or grub, stage.

When green standing trees are attacked by bark-beetles, resin is sometimes exuded by the tree to combat them, and can be seen dripping in many cases from the bore-holes. These "pitch tubes," dotted over the bark of the trunk, often distinguish infested from healthy trees before the foliage begins to wilt or change its colour. In yellow pine epidemics,

¹U.S. Dept. of Agriculture, Bureau of Entomology.

attacks may be made *en masse* by hordes of beetles upon each tree. Thousands of them perish in these attacks, being literally drowned by exudation of pitch from the tree, but the beetles persist in their attack and finally weaken and kill the tree by sheer force of numbers. When tunnels are cut by the beetles in the bark of dying trees, windfalls, or logs, in which the resin can no longer flow, no pitch tubes are formed, and the presence of beetles is betrayed only by the boring excrement lodged in the bark crevices below the tunnel entrances.

The life histories and habits of the various species of *Dendroctonus* are similar. Adult beetles emerge from the bark of recently killed trees during the summer and enter the uninjured bark of either dying or living trees. Each pair of beetles bores a round entrance hole through the bark to the wood surface and then continues the entrance tunnel as an egg-tunnel between bark and wood, but mainly in the inner bark, for about six inches. The female deposits the eggs along the sides of this egg-tunnel; the grubs, on hatching from the eggs, excavate individual mines in the inner bark and later between bark and wood, more or less at right angles to the main egg-tunnel. The grubs, or larvae, become mature towards the end of the season, and either pass the winter under the bark as grubs

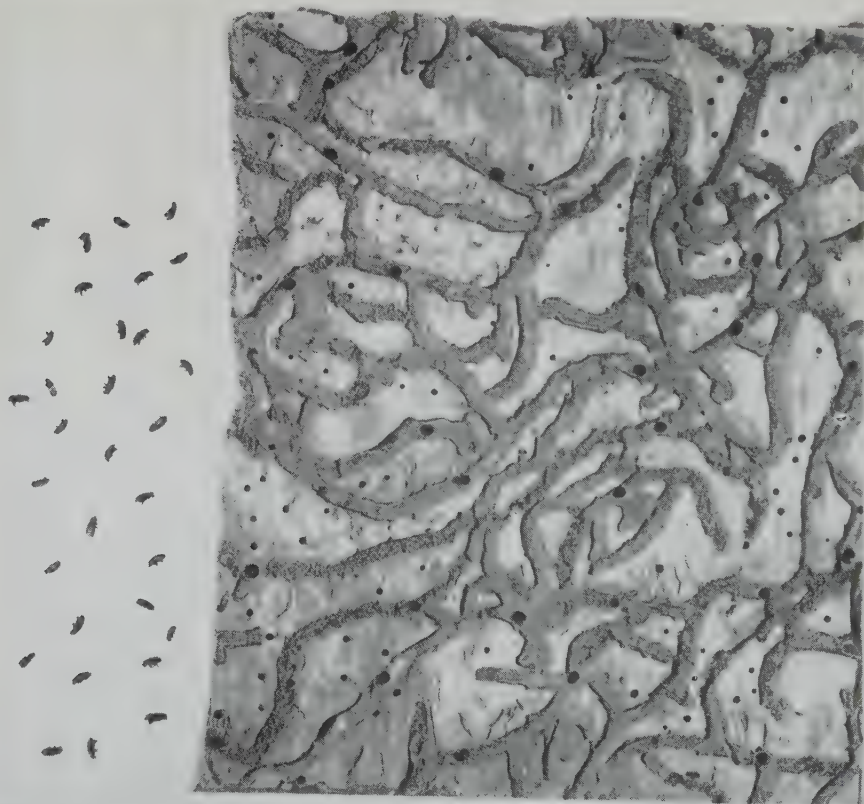


PLATE 51—Galleries of a bark-beetle in the inner bark of Western Yellow Pine

or transform to adult beetles before the winter, remaining beneath the bark until the following June or July. During the summer the beetles emerge from the bark of the trees in which they have bred and attack fresh standing trees (seldom the same tree), windfalls, or logs, in the neighbourhood. This brief outline of the life of a *Dendroctonus* will serve to indicate how bark beetles live.

As the work of bark-beetles in wood is confined to the bark and the wood immediately beneath it, the defects produced by them in lumber usually take the shape of small wounds. In resinous species the wounds made by bark-beetles often produce accumulations of resin, forming pitch-pockets and other pitch defects, which, when subsequent growth of the wood has covered them up, may be found well within the inner portions of the trunk. When such cavities are filled with bark (as described in Chapter I), they are sometimes referred to as bark-pockets. Small



FIG. 20—BARK-POCKETS, OR "BLACK STREAK"

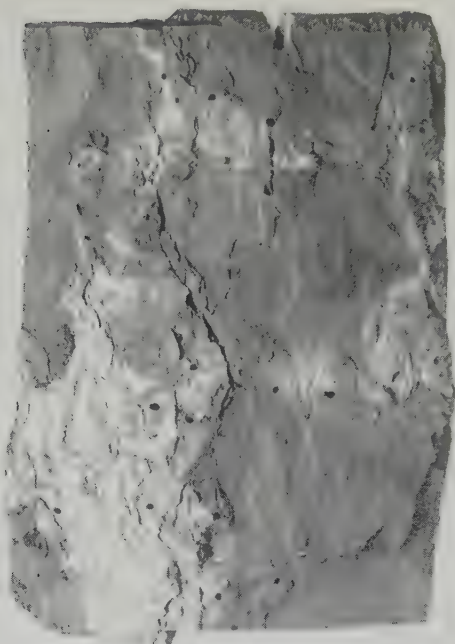
Common in Western hemlock. Caused by the larvae of certain insects.

wounds of a similar nature are also made in western softwoods by the maggots of certain flies and moths, working in the cambium and the layers adjacent to it. They are very prevalent in Western hemlock, producing the characteristic defect known as "black check" or "black streak," especially at elevations below 1,800 feet on the Coast.² As the defect is always the result of injury to the living tree, it is not preventable.

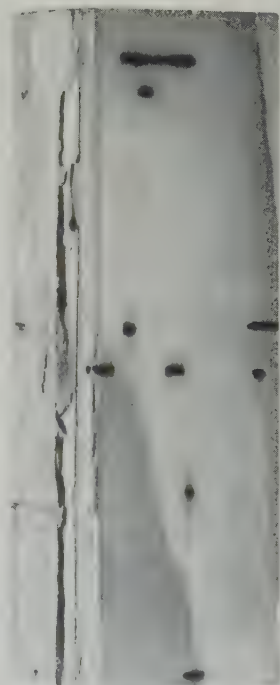
The holes of woodpeckers are often found in insect-infested trees; these birds feed upon the young grubs. In the yellow pine region beetles are said to carry in with them spores of the blue-stain fungus, which thereby infects the wood; but there has so far been no practical confirmation of this theory (see Plate 51).

Wood-boring Insects, unlike bark-beetles, do not confine their energies to the bark and the superficial sapwood, but actually bore their tunnels into the wood of the tree, radially or longitudinally, producing characteristic defects which may be much more damaging in their effect than the shallow wounds made by bark-beetles. For convenience, the work of

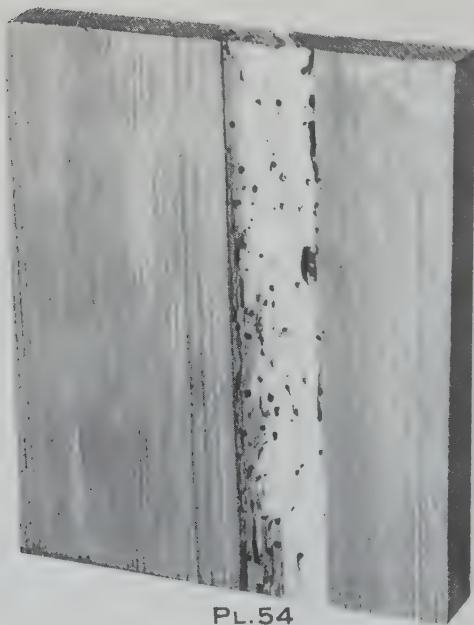
²Burke, H. E. Black check in western Hemlock. U.S. Dept. Agriculture, Bureau of Entomology, Circ. 61, 1905.



PL.52



PL.53



PL.54



PL.55

(For legends see foot of page opposite)

wood-boring insects may be divided into two types, namely, those caused by ambrosia beetles, and called "pinworm holes," and those caused by larger wood-borers, known as "grubworm holes."

Beetles belonging to the numerous group of wood-borers known as pinworms or ambrosia beetles confine their attack, for the most part, to sapwood. They are very prevalent in Coast timber and do much damage, sometimes penetrating as much as ten inches radially into the trunk; as a rule, the borings made by pinworms are not more than one-tenth of an inch in diameter, and seldom penetrate more than 3 to 4 inches into the wood. The insects are known as ambrosia beetles because they feed upon certain fungi which grow upon the walls of their boring tunnels. The tunnels are always open, and are not filled with dust; they are made by the small, adult beetles, or (after the eggs are hatched) by their larvae or grubs. In some cases the wood about these tunnels becomes discoloured, owing to the spread of the fungi. Ambrosia beetles or pinworms seldom attack healthy timber; they are more likely to attack injured or dying timber, and most likely to attack fallen timber, logs, and recently cut stumps. They are particularly injurious to fire-killed timber, but never attack decked, dry wood. They have been reported as attacking the wood of wine casks and similar containers, but this is rare, habits of such a nature being more common in the tropics than in colder climates. A great deal of injury is caused by these pinworms or pinhole borers, and they are becoming more numerous as cutting becomes more extensive and debris accumulates in the woods. The term "pinhole" owes its origin to coopers and stave-makers, who sometimes plug up the holes with little wooden pins.

The activities of wood-boring grubs are chiefly confined to logs, down timber, fire-killed timber, and lumber used for construction purposes. When they occur in living trees, they may be partially or wholly occluded by subsequent growth of the wood, or may produce resin defects. The borings are roughly oval or circular in cross-section, may be one-half inch or more in diameter, and sometimes penetrate deeply into the heartwood. The adult insect does not bore these holes; they are due solely to its young, or larvae. The smaller wood-borers naturally bore small holes, but some of the large borers may bore small holes at first until the grubs increase in size. The cavities are usually filled with boring excrement, and are commonly known as "grubworm holes."

In grading, pinworm holes are not considered to affect the strength of a piece very materially, and are admitted, within certain limits. Grub holes $1/64$ of an inch to $1/16$ of an inch in diameter are classed as pinworm holes; small holes of this nature are made by various "powder-post" beetles, as well as by ambrosia beetles. They can be distinguished from the holes of ambrosia beetles by the absence of the black fungous linings to their tunnels. Grubworm holes, being larger in diameter, have a more serious effect on the strength and appearance of a piece of lumber than pinworm holes.

PLATE 52—Entrance holes of "pinworms" in the bark of Sitka Spruce
(Reduced to about half size)

PLATE 53—"Pinworm" holes in Western Hemlock

PLATE 54—"Pinworm" holes in Western Red Cedar

The borings are confined to a pipe of "internal sapwood" which contains incipient decay. In this case the borings are the work of a "powder-post beetle," not an ambrosia beetle. (Reduced to about half size)

PLATE 55—"Pinworm" holes in Western Hemlock

Note the dark linings of the tunnel walls; this is characteristic of the borings of ambrosia beetles.

If special precautions are not taken against insect attack, great damage may occur to logs left in the woods during summer and autumn, especially to fire-killed material. Such logs may have their sapwood riddled by pinworms, and both heartwood and sapwood may be perforated by round-headed borers and other timber-worms. Logs placed in water, or barked within three weeks from cutting, will be generally free from injury. The beetles do not deposit their eggs upon bare wood, the young grubs requiring the softer inner bark for their first food, so that peeled logs are immune from attack. Unbarked logs piled loosely in the open escape serious injury if the bark dries rapidly. Covering the logs in the woods with brush affords a very good measure of protection by excluding sunlight from the surface of the logs. Poisonous chemical sprays have been used with success in repelling insect attack upon valuable logs, and, as long as the bark is left upon logs thus treated, the wood will not be discoloured.³

Even after lumber leaves the saw, and after it has been seasoned, it may be attacked by borers. In fact, from the seedling stage to the stage when it is in process of decay, in the forest or after manufacture, wood is liable to insect attack, as long as conditions favour such attack. The demolition of decaying timber is often accelerated by the work of "white ants," "carpenter ants," wasp-like "horn-tails," and "carpenter bees"; in addition to the classes of wood-boring insects previously mentioned, white ants are especially prevalent. Other types of insects found in old, exposed, decaying timber are parasites of or predators upon the wood-boring forms, while other species merely seek shelter in the tunnels of the wood-borers. Among the latter are certain beetles, roaches, earwigs, "spring-tails," Lepismids, bees, and wasps.

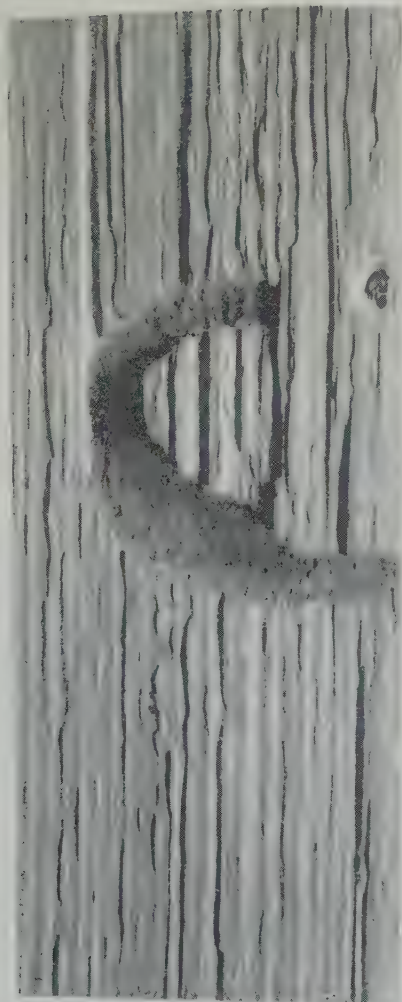
In addition to defoliating insects, the various bark-beetles, and beetles which bore in timber, there are moths, beetles, and chalcid flies which work in the cones of the pines and other conifers; also a number of others which cause damage to limbs, twigs, and trunks, such as the Douglas fir pitch moth, the pine pitch moths, and the Western spruce-gall aphid.

Termites, or "white ants," do a great deal of damage in the Coast region about Vancouver to logs in the woods, posts and poles, lumber in storage, structural timbers, foundations of buildings, etc. Special mention is made here of termites ("white ants") because of the impression many people have that they are really a tropical or sub-tropical pest, and are not found as far north as British Columbia. Very few North American termites have habits which make them conspicuous, except during the annual colonizing swarm; hence they generally escape notice until they become injurious.

Termites are not ants; they differ from true ants in habits, life history, and structure. True ants have a narrow waist, so that the popular term, "white ant," is quite misleading and untrue, applied to the termite family as a whole.

Termites are of two classes; one comprised of subterranean species (*Reticulitermes*, *Amitermes*), and the other of species whose habitat is not underground (*Kalotermes*, *Cryptotermes*). These latter do not burrow in the ground, but in a winged condition attack wooden structures directly, and can even enter at an unbroken surface where there are no checks or holes. Unlike the subterranean species these termites can exist in wood with less than the normal air-dry moisture content. The damage done by them is great, but is not nearly as great as that inflicted by the underground species. The latter live in nests in the wood of dead trees, or

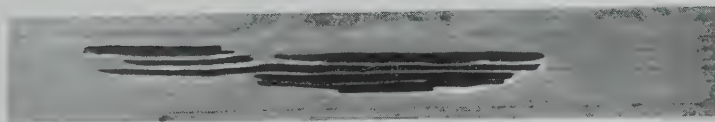
³Craighead, F. C. Experiments with spray solutions for preventing injury to green logs. U.S. Dept. Agriculture, Bull. 1079, 1922.



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PLATE 56—"Grubworm" hole in True Fir (*Abies* sp.)
Work of *Monochamus* sp.

PLATE 57—Work of termites in a piece of Douglas Fir flooring

PLATE 58—Work of black "carpenter" ants in a 12-inch board of True Fir

decaying logs or stumps in the forest, in the foundation timbers of buildings, fences, or other wood structures in contact with the ground, or in a labyrinth of underground passages in the earth, usually underneath wood or vegetation. An average colony contains several thousand "ants." Owing to their subterranean habits and great numbers, it is often difficult to destroy them once they are established in a building. Coming up from their underground galleries, they work in the interior of the wood and leave intact a protective outer shell, so that the damage is often quite unsuspected until the final collapse of the outer shell. Termites usually follow the grain when working in solid wood. They prefer decaying or moist wood, and dark, warm, moist places. They make use of a mixture of moist earth and finely digested, excreted wood in creating more favourable moisture and shelter conditions for themselves, and can pass over substances they cannot penetrate (such as metal, brick, or stone, or concrete foundations) by means of shallow shelter-sheds, made of earth and excrement, extended from the ground.

Greenhouses and garden structures are very liable to attack by "white ants," and construction timber in bridges, wharves, etc., telephone and telegraph poles, mine timbers, railway ties, posts, lumber stored on the ground or even in sheds, wooden bracing for cables, conduits, water tanks, windmills, silos, wood-pulp products, etc., may also be attacked by them. The best way to prevent attacks of termites upon lumber is by keeping the lumber as dry as possible and away from damp ground. The foundations of buildings and storage sheds should be on concrete posts or creosoted timbers, and ample ventilation should be provided underneath such structures. It may be difficult to eliminate and stop further damage by "white ants" when once these insects have become established in the woodwork of a building. In such cases the approximate point of entrance should be sought at once by careful examination of all woodwork in contact with the ground, and it may be necessary to tear up flooring and other woodwork to do this. Foundation timbers and woodwork found to be damaged should be removed, and the ground where they were set drenched with some liquid insecticide such as kerosene oil or lye. Live steam forced into the soil will serve the same purpose.⁴

Marine Wood-borers

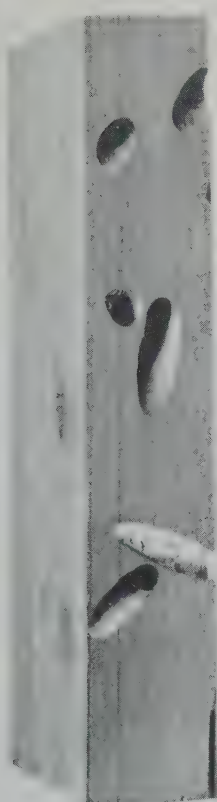
The destruction performed by marine wood-borers in British Columbia (entailing an annual loss of more than \$100,000 to the piling of cannery wharves alone) is due mainly to the activities of two species—*Bankia setacea*, a boring mollusc belonging to the *Teredo* family, and generally referred to in British Columbia as the "teredo"; and *Limnoria lignorum*, a crustacean, commonly known as the "gribble," or "sea-louse." Members of the true genus *Teredo* (comprising *Teredo navalis* and other species) have not thus far been located in British Columbia waters, though it is not impossible that they may be present. *Teredo navalis* seems to have found its way round the Horn during quite recent years and to have made its way gradually up the Pacific coast as far as San Francisco bay, where it was found in 1914, and since then has caused damage in those parts (chiefly to piling) of several millions of dollars annually.

Bankia setacea is the largest of the wood-borers working on the Pacific coast. Specimens over three feet in length and seven-eighths of an inch in diameter have been found in piling on the San Francisco waterfront.

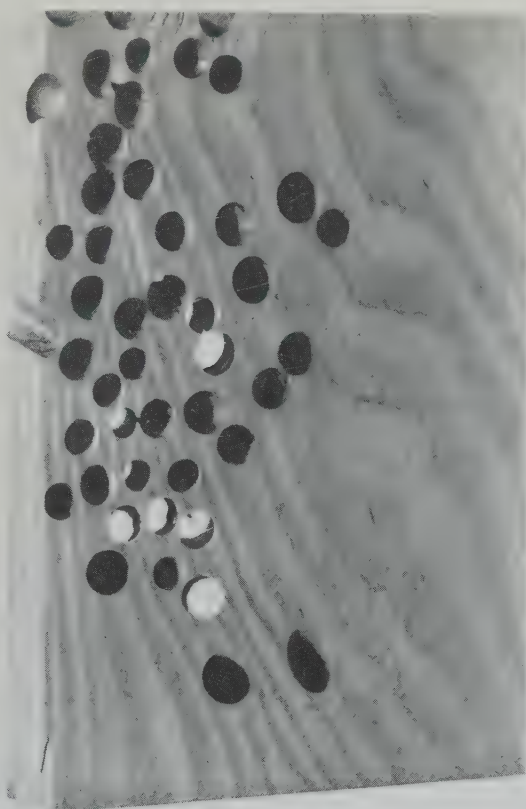
⁴Snyder, T. E. Preventing Damage by Termites or White Ants. U.S. Dept. Agriculture, Farmers' Bul. 1472, 1926.

Normally it is much smaller than this, and a diameter of about one-quarter to three-eighths of an inch is probably the commonest size. Its body is long and soft, with a hard boring shell located at the head. Two separate tubes run through the body: one tube brings in water to the stomach, and the other carries off the waste and chips resulting from the boring. Its food consists of microscopic plant life and organic particles drawn from the water into its stomach by the water-carrying tube. No food is obtained from the wood itself, the sole object of burrowing being to obtain a place of shelter. There seem to be two breeding seasons in each year; one of short duration in the month of October, and another (probably the main breeding season) commencing in the month of March; but complete information upon this point has not been assembled.⁵ It is during the breeding seasons that the large number of young produced by the animal settle upon and attack wood. These minute young individuals burrow into the wood, and grow at the same time, but never enlarge their entrance

⁵White, F. D. A note on the Breeding Season of *Bankia* (*Xylotrya*) *Setacea* in Departure Bay, B.C. Studies from the Biological Stations of Canada, new series, Vol. IV (1929), Nos. 1, 2, 3.



PL.59



PL.60

PLATE 59—Teredo holes in Yellow Cedar

PLATE 60—Teredo borings in Douglas Fir

holes. The result is that the interior of timbers inhabited by *Bankia* may be thoroughly honeycombed without the exterior showing any evidence, except the small and easily overlooked entrances, to show that attack has occurred. They do not restrict their course to sapwood, and, where the borers are not numerous, often bore obliquely deep into the wood before turning to follow the grain.

Limnoria lignorum (the "gribble") is a small crustacean borer; the largest individuals attain a length of one-quarter of an inch and are one-third as wide. Unlike *Bankia*, *Limnoria* produces few young, which have no free-swimming larval stage; after the eggs are hatched, the progeny are ready at once to assist in the burrowing process near the parent. "For this reason the spread of *Limnoria* is like the growth of a lichen or the spread of the mange or itch. There are no precise data as to their breeding seasons and length of life. Young and eggs are found throughout the year, though it is probable that reproduction is more rapid during the warm season."⁶

Limnoria destroys piling by the growth of its interlacing, branching burrows into the surface of the wood. Breaking away of the honeycombed fragments by tides and sea-currents intermittently exposes fresh sections of the interior to attack, so that the diameter of a piece of piling may be reduced by this means as much as two inches each year. *Limnoria* is frequently found in association with *Bankia*. *Bankia* probably attacks the wood first, because of the difficulties in the way of attachment of the young individuals to wood which has already become well infested by *Limnoria*. The action of *Limnoria* upon the outer surface of the wood seems to have the effect of driving *Bankia* further in and increasing its activity.

Both *Bankia* and *Limnoria* thrive only in salt water, and when the salinity of the water becomes low, they seem unable to live—especially *Limnoria*. Apparently open-sea conditions are best for their development, while organic pollution of water in limited quantities encourages their growth. When the salinity of the water becomes low enough they are unable to live, so that logs stored in fresh-water ponds or booms are immune from attack. Logs boomed on tidal flats, when they are alternately afloat and stranded, seem to be impervious to attack from *Limnoria* or *Bankia*.

Log booms in False creek (tide-water), Vancouver, have been known to be severely attacked by *Bankia*. Any logs of British Columbia softwoods which are floating in tide-water for several months are likely to be attacked during that time by "teredos," sometimes so severely as to be rendered unmerchantable. Spruce logs, together with Western hemlock, the true firs, and Western red cedar, are very susceptible to attack by *Bankia*, possibly on account of their low resin content. Douglas fir is considerably less subject to attack by *Bankia* than the other merchantable conifers.

"Teredo" holes are quite a common defect in common lumber, and have the same degrading effect as "grub-worm" holes of the same size. They can be distinguished from the latter by the fact that they seldom, if ever, contain boring dust, and are uniformly circular in cross-section, while grub-worm holes usually contain boring excrement and are often irregular in cross-section. The work of *Limnoria* in manufactured lumber is seldom apparent, because it "chews" away the wood uniformly from the outside, and the affected parts are readily trimmed off.

⁶Kofoid, C. A. San Francisco Bay Marine Piling Survey, 1921.

Protection of Piling from Marine Organisms

The damage done to piling is naturally greater than that done to floating logs because of the usually longer period of exposure of the former. Protection of marine piling from the attacks of marine organisms can be ensured either by the application of external coatings to the pile or by preservative treatments.

Experience has shown that marine borers require only a very small area of exposed surface in order to gain entrance to and completely riddle a pile, so that, to be effective, all external coatings should maintain an absolutely intact covering over the wood, while preservative should penetrate every portion of the surface layer. Where the piling is exposed to heavy waves, shocks from floating debris, etc., external coatings are unsatisfactory, since one blow from a floating log is often able to destroy the protective covering of a pile. External coatings need be applied only to that portion of the pile exposed to attack, that is, between high-water mark and the mud-line.

Leaving bark upon the pile provides adequate protection as long as the bark remains intact, but it is liable to be broken off in places as a result of blows from floating objects or waves. If the bark above the water line is allowed to remain, it unfortunately offers an excellent breeding-place for wood-destroying fungi and insects. Cement casings are effective only as long as the pile is protected from shock or vibration, and various paints and tars, even though applied when hot and reinforced with burlap, afford only temporary protection. Of the external protectives in use, metal sheathing, consisting of thin sheets of copper or zinc fastened over the exposed portion of a pile, gives the most effective service, but this is an expensive method to employ.

Creosote treatment has been found to be the most effective and economical method of preservation up to the present time. Creosote is forced into the complete length of the pile under pressure, applied in a closed cylinder under proper temperature conditions, and care is taken to ensure that penetration is made to a sufficient depth to prevent blows from floating objects exposing the untreated interior. Instances may be quoted where creosoted piling has lasted for forty years; on the other hand, poor methods of treatment with poor grades of creosote give correspondingly poor results.

APPENDIX A

LIST OF THE CHIEF FUNGI CAUSING STAIN AND DECAY IN WESTERN SOFTWOODS

W.P. (Western white pine), E.S. (Engelmann spruce), D.F. (Douglas fir), Y.P. (Western yellow pine), W.H. (Western hemlock), W.R.C. (Western red cedar), L.P.P. (Lodgepole pine), T.F. (True fir—including amabilis fir, grand fir, and alpine fir), W.L. (Western larch), S.S. (Sitka spruce).

Scientific and common names of fungus	Class of defect	Trees commonly attacked	Description of fruiting bodies: whether annual or perennial	Incipient decay	Typical decay
1. <i>Trametes Pini</i> (<i>Porodaddeia Pini</i>) Ringscale fungus. King rot. White pocket rot. White honeycomb rot. Red rot. Pecky wood rot. Red heart.	Trunk rot. Occasionally found as a butt rot. A white pocket rot.	D.F., W.P., Y.P., T.F., L.P.P., E.S., S.S., W.R.C., W.H., W.L. Attacks all conifers.	Fruiting body hoof-shaped or shell-shaped, hard and woody, the upper surface dark-brown, rough, with concentric raised zones; interior brown; pores usually large and irregular. Perennial.	Red, brown, or purplish discolorations in patches in the wood.	Formation of white cellulose pits in the wood. In final stages the annual rings may separate.
2. <i>Fomes officinalis</i> (<i>F. Laricis</i>) Larch fungus, Chalky quinine fungus, Red rot. Dry rot.	Reddish-brown heart rot. A brown cubical rot.	All coniferous trees, but principally W.L., Y.P., D.F., E.S., L.P.P.; also grows in stored lumber, and in construction timber.	Large, hoof-shaped, globose, with a white, roughened, chalky upper surface which may be easily rubbed off. When young the fruiting bodies are soft and watery; when old they are brittle. Perennial.	A uniform, purple discoloration. In Douglas fir it may take the form of a deep violet-coloured stain; or a reddish-purple stain; or a faint brown discoloration.	Wood is a brownish-red crumbly mass, with sometimes conspicuous chalky felts of mycelium filling cracks in the wood.
3. <i>Polyporus sulphureus</i> (<i>Loetiporus speciosus</i>) Sulphur fungus, Brown checked wood rot, Red rot.	Reddish-brown heart rot. A brown cubical rot.	All important conifers, but principally T.F., W.L., D.F., W.P., E.S., Y.P.	Fruiting body best method of distinguishing between this fungus and <i>F. officinalis</i> . At first sulphur-yellow, soft, watery, somewhat sponge-like knots of mycelium. These grow larger and form shelves one to several inches wide and overlapping. Upper surface of shelves is bright orange-yellow marked with reddish areas, lower side sulphur-yellow, honey-combed and Frutting bodies tough, watery. Annual.	Early and typical stages of this rot very similar to <i>F. officinalis</i> .	

4. <i>Polyporus Schweinitzii</i> (<i>Phaeolus sisoriformis</i>) (<i>Polyporus mollis</i>) Velvet top fungus. Red brown rot. Cubical butt rot. Stump or ground rot.	A.S.S., D.F., W.R.C., W.P., Y.P., I.P.P., T.F.	Soft, red-brown, toadstool-like bodies with a circular, undulating top. The top may occasionally be as much as one foot in diameter. Generally on ground near foot of tree. Annual, and not frequently found.	Faint yellowish or brownish discoloration.	Wood yellowish. Splits along certain medullary rays and annual rings into cubical, soft, and cheesy masses. It finally becomes brittle charcoal-like, and red-brown in colour. Occasionally has thin white sheets of mycelium which have the odour of turpentine.
5. <i>Echinodontium tinctorium</i> Indian paint fungus. Stringy brown rot. Stringy red-brown heartwood rot.	W.H., T.F., D.F., E.S.	Hoof-shaped bodies. Hard and woody, grey or black on upper surface with concentric growth zones. Inside of sporophore brick-red in colour; lower surface covered with numerous large and firm straw-coloured or grey spines. Perennial.	Wood stained yellow; or else light-brown or tan-coloured pipes extending in a radial direction.	Wood becomes a brown, fibrous, stringy mass, marked with rusty, red streaks.
6. <i>Fomes piniticola</i> (<i>Fomes marginatus</i>) (<i>Fomes unguiculatus</i>) (<i>Polyporus ponderosus</i>) Brown crumbly rot. Belt rot. Dry rot. Red-brown sapwood rot.	Found on all conifers, especially D.F., W.L., T.F., W.H., S.S., E.S.	A conspicuous conch or bracket. Perennial. Colour of the top black or brown, with margin yellowish in early summer and later reddish-yellow or deep red. Margin has a varnished appearance. Under surface is yellowish-brown in colour.	Sometimes grey-white, irregular spots seen in longitudinal section with light brown centres; more frequently the incipient decay simply evinces a faint yellow colour, not readily discernible.	Wood reddish-brown, crumbly, brittle, cubical. Cracks and checks filled with white mycelial felts, which are larger and non-resinous as compared with the felts of <i>P. Schweinitzii</i> .
7. <i>Fomes roseus</i> Brown pocket heartwood rot. Rose-coloured Fomes.	D.F., W.L., S.S., E.S., W.P., Y.P., W.H.	Perennial. Either a thin shelf with an irregular surface, or a thick, hoof-shaped, rose-coloured body. Upper surface may become black with age, while margin and lower surface are pinkish. Interior pinkish.	Long, cylindrical, pointed pockets of brown, friable, decayed wood, which may be one to several feet long.	The pockets merge later and form larger areas of decay. Decayed wood brown and easily pulverized.
8. <i>Fomes annosus</i> (<i>Trametes radiciperda</i>) Brown rot.	All conifers are affected to a certain extent; but it is carried as common on W.P.	Perennial. Shelving bodies with a light-brown upper surface and white to yellow lower surface.	Variable with different hosts. Generally a bluish discoloration, changing to a dirty yellow; finally brownish or reddish-brown in colour.	Small, elongated, white pits filled with celluline material appear. They may have black spots in their centres. In final stages the wood is honeycombed with these pits.

LIST OF THE CHIEF FUNGI CAUSING STAIN AND DECAY IN WESTERN SOFTWOODS—Continued

W.P. (Western white pine). E.S. (Engelmann spruce). D.F. (Douglas fir). Y.P. (Western yellow pine). W.H. (Western hemlock). W.R.C. (Western red cedar). L.P.P. (Lodgepole pine). T.F. (True fir—including amabilis fir, grand fir, and alpine fir). W.L. (Western larch). S.S. (Sitka spruce).

Scientific and common names of fungus	Class of defect	Trees commonly attacked	Description of fruiting bodies: whether annual or perennial	Incipient decay	Typical decay
9. <i>Polyporus Ellipticus</i> (<i>P. anceps</i>) (<i>Tyromyces Ellipticus</i>) Red ray wood rot. Red heart. Red rot. Grey rot. Top rot. White pocket rot.	Top rot. A white pocket rot.	Y.P.	Annual. White, flat, encrusting layers.	Central heartwood becomes reddish-brown.	Reddish-brown part becomes greyish-white, is decayed and easily pulled apart. Decayed wood is soggy and contains much water. White celluline pockets form, similar to those of <i>T. Pini</i> . Red rays with a white core extend from the decayed centre to the bark. Fungus very rapid in its action.
10. <i>Polyporus borealis</i> (<i>Spongipellis borealis</i>) Cuboidal wood rot.	Heartwood rot. Sapwood rot occasionally. A white mottled rot or cuboidal rot.	S.S., E.S., W.H.	Clusters of shelf-like bodies are formed. Upper surfaces white and shaggy; lower surface with roundish or sinuous openings. Fruiting body white to yellow and soft and spongy. Annual.	Numerous long, parallel strands of white mycelium work through the wood. These disappear, leaving gaps in the wood.	Because of the perforations the wood splits into cubes, and fine white strands of mycelium continue to grow through the wood, splitting it into further cubes.
11. <i>Canoderma oregonense</i> Water soak. White rot.	Heartwood rot. A white pocket rot.	S.S., D.F., and W.H.	Annual, or may persist for several years. Large brackets with conspicuous, encrusted, varnished surface. The lower surface is brown, and the texture is a spongy mass of interwoven threads, more or less pulpy, and white or cream in colour. The bracket is attached to the tree by a stout stalk, which may be as long as the bracket is wide. The bracket may be 6 inches in diameter, and is heart-shaped, or kidney-shaped.	Dark, sudden appearance to the wood in early stages. When this dries out, the wood shows little signs of incipient decay.	The spring-wood is reduced to a thin cellulose layer, later involving the summer-wood. The wood separates into thin sheets showing a light, spongy, straw-coloured rot with numerous large, black spots and ramifying black lines.

12. <i>Poria Weirii</i> Brown cedar Yellow laminated rot. Brown rot.	Root and butt rot. A brown ring rot. This is probably the commonest butt rot of Western red cedar.	A.W.R.C.	Perennial. Fruiting body flat, small, stratified; brown in colour. Grows in root crotches. Forest debris about the roots sometimes cemented into a punky mass by it.	Rot yellow in colour, decaying spring-wood first and separating the annual rings.	Wood becomes brown and crumbly, with felty mycelium between the layers.
13. <i>Pholiota adiposa</i> Yellow heart rot. Scaly pholiota. Brown mottled rot.	Heartwood rot. A brown mottled rot.	T.F., W.H., W.P., E.S., of most importance on true firs.	Annual. Of mushroom type, found in clusters, yellow on upper surface, sticky when wet. Stem yellow; gills yellowish to brown.	Light yellow discolorations in early stages.	Wood yellow to honey colour, with brownish streaks. Yellowish to light tan, or white, felty masses run across the grain and separate the annual rings. Final stage is a hollow rot.
14. <i>Merulius lacrimans</i> True dry rot. Weeping fungus.	Rot of structural timber and stored lumber. A brown cuboidal rot.	All coniferous woods as far as known; also hardwoods.	Flat encrustations, rusty-brown in colour, with a greyish margin. The surface is corrugated in appearance; there are pores in the greyish margin.	Found growing in timber without any apparent moisture. In reality moisture is conducted from sources of supply by strands of mycelium, which may be very thick and cord-like. Incipient decay a brownish discoloration not readily discernible.	Wood shrunken, yellow-brown in colour and filled with cubical shrinkage cracks, which are sometimes filled with white mycelium. Wood in final stages can easily be crushed to a powder.
15. <i>Poria incrassata</i> <i>Poria xanthia</i> Others of genus <i>Poria</i> .	Rot of structural timber and stored lumber. A brown cubical rot.	All coniferous woods as far as known; also hardwoods.	Flat encrustations, usually nearly white in colour throughout. The top of the growth may be olive, orange, or yellow in colour. Pores on under surface. The bodies turn brown or black with age.	Found growing in timber without any apparent moisture. In reality moisture is conducted from sources of supply by strands of mycelium. Incipient decay a brownish discoloration.	Wood shrunken, yellow-brown in colour and filled with cubical shrinkage cracks, which are sometimes filled with white mycelium. Wood in final stages can easily be crushed to a powder.
16. <i>Poria vaporaria</i> (<i>Polyporus vaporarius</i>) Dry rot.	Rot of structural timber and stored lumber. Is also occasionally found in the woods. A brown cubical rot.	All coniferous woods as far as known; also hardwoods.	Flat encrustations, varying on fleshy colour. The outer surface is smooth.	Found growing in timber without any apparent moisture. In reality moisture is conducted from sources of supply by strands of mycelium. Incipient decay a brownish discoloration.	Wood shrunken, yellow-brown in colour and filled with cubical shrinkage cracks, which are sometimes filled with white mycelium. Wood in final stages can easily be crushed to a powder.
17. <i>Lenzites sepiaria</i> (<i>Glaeophyllum hirsutum</i>) Brown cubical rot. Laminated rot. Dry rot.	Rot of structural timber and stored lumber. This fungus greatly prevalent in railway ties, telephone poles, and other open-air structures. Sapwood attacked first. A brown cubical rot.	All coniferous woods as far as known. Attacks heartwood and sapwood.	Small, long, and narrow, or disk-like, shelf-like formations. Found singly or in clusters. Either gills or pores on the under surface. Colour varies from white to black.	Darkening in colour of normal wood.	Sometimes the spring-wood rots first, producing a laminated rot. Considerable shrinkage occurs. In the final stages the wood can easily be crushed to a powder.

LIST OF THE CHIEF FUNGI CAUSING STAIN AND DECAY IN WESTERN SOFTWOODS—Concluded

W.P. (Western white pine), E.S. (Engelmann spruce), D.F. (Douglas fir), Y.P. (Western yellow pine), W.H. (Western hemlock), W.R.C. (Western red cedar), L.P.P. (Lodgepole pine), T.F. (True fir—including amabilis fir, grand fir, and alpine fir), W.L. (Western larch), S.S. (Sitka spruce)

Scientific and common names of fungus	Class of defect	Trees commonly attacked	Description of fruiting bodies: whether annual or perennial	Incipient decay	Typical decay
18. <i>Coniophora cerebella</i> (<i>Coniophora paleana</i>) Dry rot.	Rot of structural timber and stored lumber. A brown cubical rot.	All coniferous woods as far as known; also attacks hardwoods.	Forms a smooth, brown, thin, membranaceous layer on the surface of infected timber. Sometimes the surface is warted or convolute. The fruiting body closely resembles that of <i>Merulius lacrimans</i> .	Incipient decay shown by a brownish discoloration.	Wood is shrunken and yellow-brown in colour, and filled with cubical shrinkage cracks. In final stages the wood can be crushed to a powder between finger and thumb.
19. <i>Lentinus lepideus</i> . Brown cubical rot. Dry rot.	Prevalent in structural timbers, especially timber in contact with the ground. A brown cubical rot.	All coniferous woods as far as known.	Mushroom-like. Top and stem are pale yellow to brownish in colour and umbrella-shaped. Gills on under side. The stem is stout and fibrous and may be central or eccentric. Annual.	Darkening in colour of the normal wood.	Wood is shrunken and yellow-brown in colour, and filled with cubical shrinkage cracks. In final stages the wood can be crushed to a powder between finger and thumb.
20. <i>Schizophyllum commune</i> White rot.	Attacks structural timber.	Wide-spread on softwoods and hardwoods.	Small, usually projecting out not more than 1½ inches. White to greyish, thin and flexible; gills on under side. At times attached to wood at centre of back and presenting a circular outline.	Although wide-spread, deteriorates lumber only slightly.	
21. <i>Stereum fasciatum</i> .	Attacks structural timber and dead and down timber. A white pocket rot.	Appears to be most prevalent in Western hemlock lumber.	Small, with a smooth under surface. Top roughly corrugated, thin and flexible, with individual shelves growing one above the other. Colour of top greyish to creamy.	Darkening in colour of wood.	Distinct pockets are formed in the wood, irregularly developed, containing cellulose fibres. Black spots or flecks are often found in the decayed areas.
22. <i>Polystictus abietinus</i> (<i>Polyporus abietinus</i>) Sapwood rot.	In structural timber, lumber yards, and especially in lumber which is in contact with the soil. Also common in dead softwood trees, whether standing or down. A white ring rot.	Infects sapwood more often than heartwood. Found in all dead, coniferous wood.	Small, shelving brackets with pores on lower sides.	Small, shallow, narrow cavities are formed in the wood, separated by thin partitions of sound wood.	The cavities may extend, causing the rings to separate. In its final stages of decay the wood becomes very spongy.

23. <i>Green stain. Chlorosplenium aeruginosum</i> (<i>Peziza aeruginosa</i>) Green rot.	A green rot..	Prevalent in all softwood timber exposed to the elements; also in hardwood timber.	A small, saucer-shaped, green structure with a stem.	This fungus stains the wood a bright, sap-green colour.	The whole of the piece may be stained a verdigris-green colour, and eventually a stringy rot is produced; but the action of this rot is slow.
24. <i>Blue stain generally Ceraulostomella</i> (various species); <i>Ceraulostomella pilifera</i> is the commonest of the genus.	Sap-stain. Sometimes in heartwood.	Serious in Y.P. Also found in W.P. and other softwoods.	Appear to the eye as tiny black specks with a "bristle" attached to each. These are <i>perithecia</i> . It may also reproduce by means of <i>conidia</i> . These are tiny spore-like bodies borne in groups at the extremities of hyphal branches.	Blue stain in spots or streaks.	May entirely colour sapwood and part of heartwood a bluish-black colour.
25. <i>Brown stain, also a black stain, due to species of Graphium, Hormodendron, Hormiscium, and others.</i>	Sap-stains. Sometimes in heartwood.	Serious in Y.P., L.P.P., also found in W.P.	These species reproduce by means of tiny bodies which grow in groups at the ends of hyphal branches, named <i>conidia</i> . The main method of reproduction of <i>Graphium</i> is by upright, cylindrical black to brown fruiting bodies, 1-3 mm. in height, known as <i>stromata</i> . They bear at their tips globules, which are aggregations of spores.	Brown or black stain in spots or streaks.	May entirely colour sapwood and part of heartwood a dark chocolate-brown colour, or a black colour.
26. Green, red, pink, crimson, lilac, violet, lemon, yellow, or orange stains caused by species of <i>Fusarium</i> and <i>Penicillium</i> .	Sap-stains, occasionally in heartwood.	Pines. Have also been noticed in D.F.	<i>Fusarium</i> reproduces by means of <i>conidia</i> and by <i>chlamydospores</i> . These latter are bodies caused by the enlargement or modification of certain cells in the mycelial filaments. <i>Penicillium</i> has been noted to reproduce by <i>conidia</i> only.	Sap-stain in various colours	May spread entirely through sapwood, but rarely affects heartwood.

NOTE.—The above should not be considered as a complete list of the fungi which inhabit softwoods. There may be others of considerable importance which have not yet been located. There are others, such as the organism causing the spotty red stain of Sitka spruce, and fungi causing certain rots in Western red cedar and Western hemlock, whose existence is known only by the results of their work in wood, and whose habits and identities are themselves unknown.

APPENDIX B

NOMENCLATURE OF SOFTWOODS OF BRITISH COLUMBIA

Common name	Botanical name
Western red cedar.....	<i>Thuja plicata</i> Don
Yellow cedar.....	<i>Chamaecyparis nootkatensis</i> (Lam.) Spach
Douglas fir.....	<i>Pseudotsuga taxifolia</i> (Lam.) Britton
Alpine fir.....	<i>Abies lasiocarpa</i> (Hook.) Nuttall
Amabilis fir.....	<i>Abies amabilis</i> (Dougl.) Forbes
Lowland fir.....	<i>Abies grandis</i> Lindley
Western hemlock.....	<i>Tsuga heterophylla</i> (Raf.) Sargent
Western larch.....	<i>Larix occidentalis</i> Nuttall
Western white pine.....	<i>Pinus monticola</i> Douglas
Lodgepole pine.....	<i>Pinus contorta</i> Dougl., var. <i>Murrayana</i> (Engelm.)
Western yellow pine (ponderosa pine).....	<i>Pinus ponderosa</i> Douglas
Engelmann spruce.....	<i>Picea Engelmanni</i> (Parry) Engelmann
Sitka spruce.....	<i>Picea sitchensis</i> (Bong.) Carr.

Other softwoods indigenous to British Columbia but found in small stands or mixed with other species are:—

Black spruce.....	<i>Picea mariana</i> (Mill.) B.S.P.
White spruce.....	<i>Picea canadensis</i> (Mill.) B.S.P.
Limber pine.....	<i>Pinus flexilis</i> James
White-barked pine.....	<i>Pinus albicaulis</i> Engelm.
Tamarack.....	<i>Larix laricina</i> (Du Roi) Koch
Alpine larch.....	<i>Larix Lyallii</i> Parl.
Black hemlock.....	<i>Tsuga Mertensiana</i> (Bong.) Sargent
Rocky Mountain juniper....	<i>Juniperus scopulorum</i> Sargent
Western yew.....	<i>Taxus brevifolia</i> Nutt.

APPENDIX C

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PLATE 11. "Bird's-eye" in Douglas Fir



PLATE 22. Resin Secretion near a Burl in Douglas Fir



PLATE 25. "Mineral Stain" in Western Hemlock



PLATE 27. "Firm Red Heart"

Incipient Decay in Douglas Fir, caused by *Fomes officinalis* (often caused also by *Trametes Pini*)

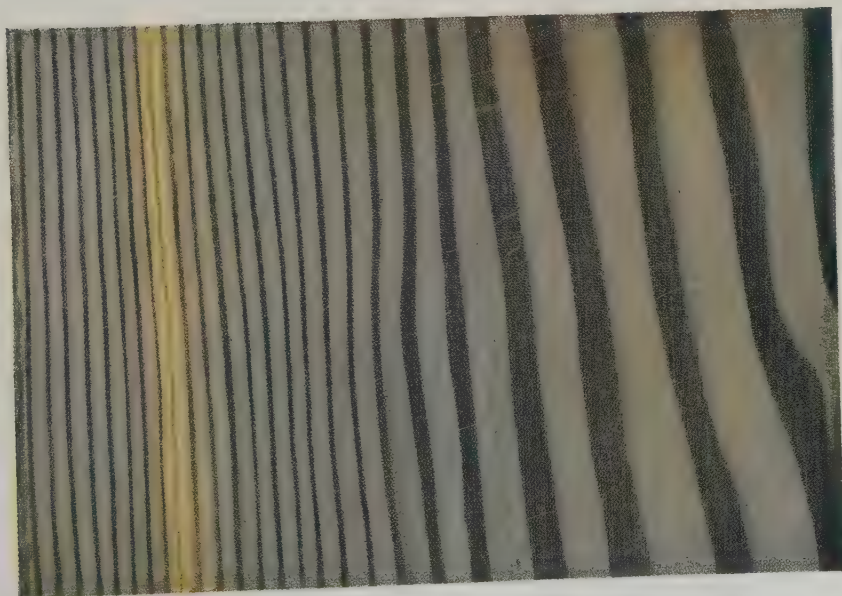


PLATE 28. "Purple Stain"

Incipient Decay in Douglas Fir, caused by *Fomes officinalis*



PLATE 29. "Soft Spots"
Typical Decay caused by *Fomes officinalis*



PLATE 30. "White Specks"
Typical Decay caused by *Trametes Pini*



PLATE 35. *Polyporus Schweinitzii* in Douglas Fir



PLATE 32. Chemical Stain in Douglas Fir



PLATE 36. *Fomes pinicola* in Hemlock



PLATE 37. *Polyporus Ellisianus* in Western Yellow Pine

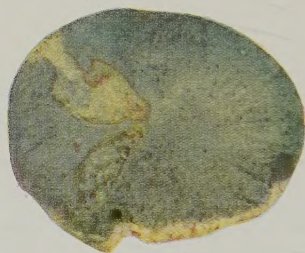


PLATE 47. Green Stain in Cottonwood
Causal Fungus, *Chlorosplenium aeruginosum*



PLATE 38. A Common Rot in Western Hemlock
Causal Fungus unknown

N.B.—Titles of Plates 38 and 39 have been interchanged; they should read as follows:
Plate 38 (above) *Poria incrassata* in Pine. Plate 39 (on opposite page) A Common Rot
in Western Hemlock (causal fungus unknown)



PLATE 39. *Poria incrassata* in Pine

(See note at foot of opposite page)



PLATE 49. Brown Sap-stain in Western Yellow Pine



PLATE 46. A Common Rot in
Western Hemlock



PLATE 48. Blue Sap-stain in
Western White Pine

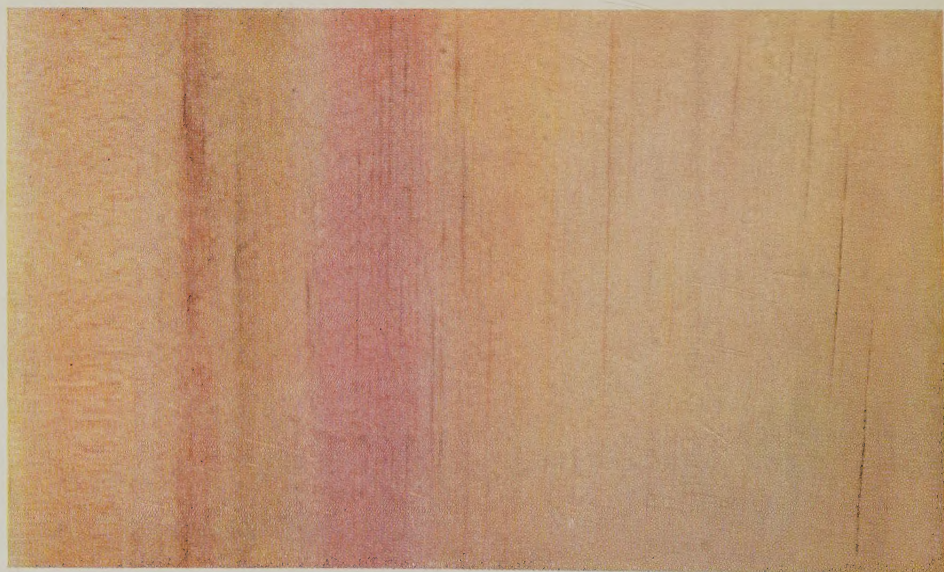


PLATE 50. Pink Stain in Western White Pine
Probable Cause, *Fusarium* sp. (a mould)